THIRD DIMENSION MOVIES

CAMERON

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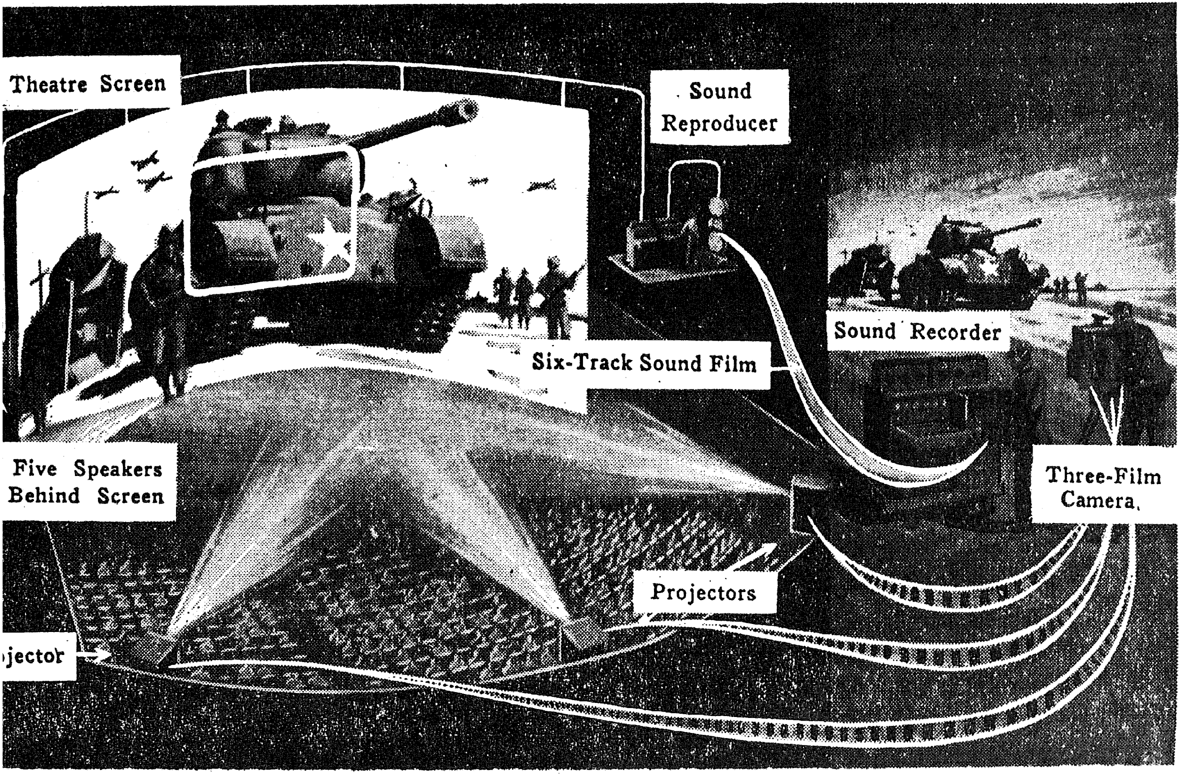
Theatre Screen
Sound Reproducer
Sound Recorder
Six-Track Sound Film
Five Speakers Behind Screen
Three-Film Camera.
Projectors
jector

THIRD DIMENSION MOVIES
AND
E-X-P-A-N-D-E-D SCREEN

BY

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oks by James R. Cameron

Servicing Sound Motion Picture Equipment
Sound Pictures Trouble Shooters Manual
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Motors and Motor Generators
Electricity for the Operator
Motion Pictures with Sound
Motion Picture Optics
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Talking Movies

The present trend in the motion picture industry to a change in "aspect-ratio" (the relationship between screen height to screen width) and third dimension films, amounts to nothing less than a technological revolution. This holds true, no matter whether a true stereoscopic, like Natural Vision, a depth deception, like Cinerama or Fox's CinemaScope, or some variant, or a combination of both, be finally adopted. Neither the third dimension picture nor the change in screen size and ratio, is new, both having been constantly in-and-out of the motion picture business, just as long as the writer can remember, and we started in the industry something over fifty years ago.

Wide film, and by that we mean a film wider than the present 35 mm standard, was used as far back as 1896, a number of cameras and projectors of that vintage, used film of varying widths up to 2¾ inches.

In the late twenties, with the advent of sound, interest was again focused on the wide film, and a change in the 3-to-4 ratio was advocated. Paramount, RCA, Bell & Howell, Fox Film and others all proposed the use of a film wider than 35 mm, each suggested a different width film, and a different screen ratio. Fox actually built the necessary equipment for the making of motion pictures using a film 70 mm wide. These pictures reached the screen late in 1929, under the name of Fox Grandeur Pictures. The screen picture was 35 feet wide by 17½ feet high, the pro-

6.00

jectors and other equipment were all hand-built by Simplex. Details of Grandeur Pictures will be found elsewhere in this book.

The stereoscope is older than motion pictures, in fact it's older than photography, the subject of binocular vision has been studied and written about since the days of Galen in the year 170.

It has been the hope and dream of several hundred of workers in the field of stereoscopy, ever since motion pictures were first introduced, to perfect a system whereby a third dimension could be given the projected picture, without the use of glasses or other mechanical viewing devices. Millions of dollars, and years of working time have gone into the attempt to perfect such a system, to date no one has been successful. Hope for third dimension motion pictures without the use of some mechanical viewing medium is something for the very distant future.

The first stereoscopic pictures were drawings viewed in instruments similar to the hand instruments introduced by Holmes and afterward found on the parlor table of most homes in the early days of photography.

It is not generally realized that the eyes see two distinct and slightly different pictures of every object on which they are directed. A simple example will make this plain:

Close your left eye and in front of your right eye, about one foot from it, hold upright the first finger of your right hand and then one foot away hold up the first finger of your left hand in a line directly with the other finger. You will find that you can see only one finger, the nearest one. Now close the right eye and open the left and you find that you can see both fingers and that the farthest away is to the left of the other. Herein we have a demonstration of what is known as binocular vision, seeing with two eyes. Our eyes are so set or placed that we are able to see around objects and estimate their lateral dimensions or solidity, to determine the shape of things, to appreciate the separation of objects at different distances and to see things in pleasing perspective. Close one eye and look about you and you find things become flat, just as the movies of today. Immediately upon opening the closed eye, you see things in perspective. That is the difference between the ordinary movies and Stereoscopic Pictures.

The separation of the human eyes averages about two and three-quarter inches and each eye sees a different view. To see stereoscopically with our unaided eyes, we must view other than flat objects or planes.

If, however, we produce two photographs of the same object, which photographs are flat, mount them side by side and use a stereoscope to view them, so that each eye sees one view only, we again reproduce the scene in relief. In fact, the relief may be increased, within limits, over that normally seen with the eyes, by taking the two views from points further apart than the normal distance between the human eyes.

The Stereoscope is an optical instrument "for uniting into one image two plane (or flat) representations as seen by each eye separately and giving to them the appearance of relief or solidity."

"In 1841 Dove showed that if one of a pair of stereoscopic pictures is outlined in blue on a white ground, and the other element in red, the two being approximately superimposed upon the same sheet, a spectator furnished with red and blue glasses will see the outlines as a single solid unit. In demonstrating this fact Dove obviously foreshadowed the work of Ducos Du Hauron." "D'Al-media, in his communication (1858) to the French Academy of Science, described how he placed in the source of the luminous rays two colored glasses (red and green); the observer views the projection through glasses of similar colors, the fusion being seen as a black and white combination in stereoscopic relief."

Theodore Brown is given credit for the following systems: 1. Placing the subject on a rotable stand revolved synchronously with the working of the taking camera; 2. Causing the camera to circumscribe the object, by making the former travel round the subject at a speed regulated by the working of the camera; 3. Using the camera on a special tripod head, designed to give an oscillation to the camera while in operation; and 4. Taking the subject in a continuous panographic direction at a speed according to the movement of the vehicle carrying the camra.

A flurry in the production of third dimension pictures took place in the early twenties. Fairall presented the stereoscopic picture "The Power of Love" at the Ambassador Theater in Los Angeles, California.

The *Film Daily* of September 30, 1922, announced "A preview of the Stereoscopic motion picture, 'The Power of Love,' to be given at the Ambassador Hotel Theater, Los Angeles, Cal." "The film received continuous applause."

Fairall projects his pictures by means of two projectors operating in unison with scenes representing one point of view being colored red in the clear portions and the other set colored blue-green.

Quoting the *Film Daily* again: "The Fairall camera has two lenses the distance apart of the humn eyes. The two films are superimposed in projection. In viewing the films, spectacles are worn with red glass over one eye and a green glass over the other eye to obtain the stereoscopic effect."

Teleview Stereoscopic Motion Pictures first shown publicly at the Selwyn Theater, New York City, during the holidays of 1922-23. This system uses two cameras for photographing and two projectors for screening. The spectator is furnished with an instrument to hold in front of the eyes, which consists of a handle, topped with a round section having openings, through which one can view the picture. This instrument contains a shutter synchronized with the two projectors, so that first one and then the other eye is uncovered in agreement with the uncovering of the pictures by the respective projectors. The shutter held by the spectator is electrically connected with the generator that drives the projectors.

This all sounds expensive and complicated but in practice it seems quite simple, while the question of expense is debatable. If a house would run stereoscopic pictures regularly, say two pictures a month, and the installation per seat is not over $10, then the cost per seat per day would be only about six cents or per show about one cent each. Over a period of time this would be negligible.

PLASTICON PICTURES

This is simply an adoption of the Du Hauron Anaglyph. The system was adopted because of its simplicity. The camera pulls down two picture areas at a time and exposes both at once. Each lens is provided with a prism so that one lens sees about 1 3-8" to the right of center, while the other sees the same distance to the left. The same camera that is used for color pictures was utilized by making a new mounting for the prisms and lenses interchangeable with the color lenses. Two exposures are made simultaneously.

All of the right eye pictures are printed on one side of double-coated film and toned red, and the left eye pictures printed on the opposite side and toned blue-green. The result is a blurred intermixture of colors and pictures.

The audience is supplied with spectacles, in order to see the pictures correctly. In this case a cardboard framework supporting two pieces of gelatine colored red and green-blue. The red glass obliterates the red-toned image but turns the green-blue toned image black. The same principle applies to the other set of pictures. The result is that each eye sees only the one picture, the two are mixed in the brain and the original scene is reproduced.

The first public demonstration of Plasticon Pictures was given at the Rivoli Theater, New York, during Christmas week, 1922.

Reading from the press notices:

New York Times: "These stereoscopic pictures have to be seen to be appreciated. Persons accustomed to viewing ordinary flat pictures cannot easily anticipate the effect of seeing every object in a scene stand out with length, breadth and thickness as it does in real life. They do just this, in Mr. Kelley's short film, which is composed of scenes in and about New York City."

The Tribune: It is the gold frame to this picture that is the real attraction this week. Dr. Riesenfeld, as a sort of warming up to the fourth dimension which he will reveal later in the Einstein pictures, probes this week into the third dimension on the screen. It is a film novelty called "Movies of the Future" introducing "Plasticon" pictures, depending upon little paper spectacles with different colored lenses, distributed by ushers, to give a stereoscopic effect. On the screen the spectator sees blurred red and green images in motion, but the colored filters cut off one of the images, so that separate pictures are presented to each eye, as in the old-fashioned stereoscope, and the combination of these gives the appearance of relief to the figures.

Plasticon pictures follow the principle set down by Nature, that each eye sees its own image. The movies of today have but two dimensions, heighth and breadth. Depth is not present and we must judge distances by size. The third dimension or depth is the basic principle of "Plasticon Pictures" and we are now able to view upon the screen pictures that have natural solidity.

All of the third dimensional systems introduced up to late in the '20's employed the use of color in making the picture and again to separate the two pictures during projection. Generally a red-orange filter was used for the right eye while a blue-green filter was used for the left eye.

With the introduction of the Polaroid light polarizing filters, the original anaglyph process was discontinued and the Polaroid filters were substituted for the colored glasses.

In 1939 J. A. Norling of the Loucks and Norling Studios in New York City produced a series of "shorts" in three dimensions. These were released by Loew's under the name of "Audioscopiks," the pictures found favorable acceptance by audiences not only in this country, but throughout the world. Norling has made a life-time study of stereoscopic motion pictures, and is recognized as an outstanding authority on the subject. A third-dimension motion picture made by "stop-motion" photography was produced by Norling for the Chrysler Corp., and was viewed by over 5,000,000 people during the run of the World's Fair in New

York City in 1939. Norling's three-dimensional camer has recently been taken over by RKO for use i their stereoscopic pictures. A method of photographing for three-dimension pictures using only one camer and one film to carry the two images, was to use "beam-splitter." This consisted of either mirrors o prisms, so placed as to split the light beam into tw different paths. The system entails a great loss o light. Natural Vision uses such a beam splitter betwee the two cameras when photographing the picture.

A proposed system in photographing and projecting "wide-screen" pictures, was to use the Newcome Anamorphoser lens. This special lens compresses th pictures horizontally on the film when photographing, and another lens is required for use on the projector when screening the picture to expand the picture. This is the system now being considered b Fox, and to be placed on the market under the nam of "CinemaScope." This is NOT a third-dimensio system, merely one in which the screen ratio is change and the picture is expanded horizontally.

The recent introduction of Cinerama on Broadway was undoubtedly responsible for the revived interest in third-dimension motion pictures. Cinerama, like CinemaScope, is not a third-dimensional picture, its huge screen proportions (the screen picture is 65 feet wide) and the "wrap-around" effect together with the use of stereophonic sound, tends to give an "illusion" of depth to the projected picture.

The box offices of those theaters showing three-dimension films, or the expanded picture, show conclusively that this new form of picture has met with public approval, and that theater audiences want a change from the old flat, two-dimension picture. Box office records have been broken in practically every theater showing this new type picture, and these crowds have been drawn into these theaters because of the new dimensions, rather than the subject matter or merit of the film story. Bwana Devil, the first full-length feature picture in three dimensions, if made on the old two-dimension standard process, would be classed as a "B" picture, and at that would have had to be "pressure" sold to exhibitors. Today this picture is outdrawing any and all of the recent Hollywood productions. Third dimension is drawing the crowds into the theaters in spite of the poor program quality of the picture story.

The series of "shorts" making up the first program for the Cinerama debut were, of course, all carefully chosen and specially made for the expanded screen. The projected Cinerama picture is far from perfect, but these imperfections have been more noticeable by the technical minded than the average theater-goer. Distortion at the extreme sides of the "wrap-around" screen is most pronounced, the overlap between pictures is noticeable (three pictures from three projectors are projected onto the screen simultaneously), and the light, and color values of the light, from the three arc lamps used in projection is not constant or uniform. These defects will, of course, be corrected in time. In spite of these defects, people are clamoring for tickets to the show; at the time of writing this, tickets are being sold three months in advance, special busses are being chartered to bring groups of people to the show from outlying cities. This demand for tickets has been created largely by word of mouth advertising by those who have seen Cinerama.

It may be that the introduction of these systems at this time will prove to be the stimulant that has been needed by the industry since the advent of home television. Both producers and exhibitors should keep in mind the fact that it is only a question of time before home television will have both color and third dimension. It is just possible that both may be introduced at the same time. It is to be hoped that the motion picture industry will now be a leader in the third-dimension field, rather than being forced into it at some later date by stereoscopic television competition. The introduction of third dimension and expanded screen pictures will, we feel sure, be highly beneficial to the entire industry. It is a matter of record that third dimension is now commonplace to the amateur photographer, and the amateur movie fan.

Every major movie studio has declared its alliance with the new third dimension or the expanded screen picture. Each are proclaiming the advantages of their respective processes. It will be well for exhibitors to give serious thought to the question as to just which of the systems will be best for his individual theater, and to remember the proposed expanded systems, such as Cinerama and CinemaScope, are NOT third dimensional.

Some of the systems are being offered on a price basis. These estimated prices now being quoted in the trade press should be thoroughly checked. For instance, one of the expanded screen systems states that the equipment will cost the exhibitor approximately $2,500.00. As these systems have to use stereophonic sound, with a multiple of speakers arranged right across the expanded screen, down the sides of the auditorium and maybe in the back of the theater, they also use a huge highly reflective screen, and special lenses on the projectors, with probably the installation of higher amperage arc lamps, generators, rectifiers, and maybe rewiring of the electrical circuit, to take care of these higher amperage accessories, to the writer, the quoted price of $2,500.00 is away too low.

Cinerama has never stated just what the cost was to install the equipment in the theater on Broadway, but it has been estimated that the equipment and installation ran somewhere between $50,000.00 and $100,000.00.

We repeat, the exhibitor will have to give full, serious consideration to the question of equipment. Don't let us forget what happened during the early days of sound.

The most important question before the industry right now is one of standardization of the new three-dimension equipment. The Motion Picture Research Council in Hollywood and the S.M.P.T.E in New York City should get together with manufacturers and exhibitors, to set certain standards for the equipment, and, as far as is practical the equipment should be interchangeable. Otherwise producers are going to lose some outlet markets for their pictures, while the exhibitor is going to have his choice of film product greatly restricted and curtailed. Without standardization the cost of equipment for these new mediums, and the cost of installation of same, will be well beyond the reach of a great number of exhibitors. We repeat, let us not forget the early days of sound.

What it will cost exhibitors to convert over to the new third-dimension or expanded screen, cannot be approximated until such time as plans are made for the standardization of equipment, and the production costs are known. Certain important accessories for the showing of the proposed expanded screen picture are not yet in production. We are referring to the special compression and expansion lens required in the CinemaScope process to be marketed by Fox.

With some of the systems, exhibitors will be forced to replace much of the present projection equipment, such as generators, arc lamps, rectifiers. Most of the systems will call for a much higher amperage at the arc. because of the loss of light now encountered in the optical train of these third-dimension installations. Screens of much larger proportions will be required for the expanded systems, and all matte screens now in use will have to be replaced with metallic screens, as a highly reflective screen is necessary.

Equipment used in the showing of Natural Vision, Norling RKO, Stereo Technique, Tri-Opticon, and all other third-dimension systems using viewing glasses, will be interchangeable. These systems and the equipment necessary for showing these third-dimension picturs are not interchangeable with the Fox CinemaScope or Cinerama or other proposed expanded screen systems.

The exhibitor will have to decide which of the two systems will be best for his theater, either third-dimension or expanded screen. The two systems are entirely different and have nothing in common.

Cinerama cannot possibly be considered for use in the smaller theaters, or in theaters having a narrow auditorium. This system calls for the installation of three projectors, in three projection booths, located in three different locations on the ground floor of the theater. One projection booth is placed directly in front of the huge screen, one at the extreme left of the auditorium, and the third at the extreme right of the auditorium. Each of these booths have to be the same distance from the screen (the projector light "throw" has to be exactly the same in all three projectors), so the distance these booths are placed from the screen is determined by the width of the auditorium. In a narrow auditorium, the booths would have to be installed away down front, and thus make useless all the seating behind these booths.

The operating costs of this system is well beyond the small theater owner. A minimum of four projectionists are required to operate the system, and all present-day booth supply costs, such as carbons, light, etc., will be six times as much. To the writer, Cinerama will be forced to place its equipment in large presentation houses in the larger cities throughout the country, probably one installation in each city.

Fox's CinemaScope is a modified Cinerama process, using only one projector in the regular booth for showing the pictures. The extra width of the screen picture is obtained by the use of a special imported expanding lens which is introduced into the optical circuit on the projector.

CinemaScope, like Cinerama, uses stereophonic sound (directional sound). This type of sound reproduction is necessary to help in creating the depth illusion, on the screen. The employment of CinemaScope will call for two operators, like the third-dimension systems. While only one projector is used at a time, an extra projectionist will be required in the booth to operate the sound controls, to obtain sound perspective.

The installation of third-dimension systems like Natural Vision will call for two projection machines to run simultaneously. Thus it will be necessary to have an intermission midway in the show, to allow the projectionists time to thread up the film for the second half of the program, and also to retrim his arc lamps, as these will now have to burn continuously for a period of approximately one hour. Extra-sized reels are used, allowing for the entire show being placed on two reels. Another intermission will be necessary between each show.

The introduction of a polaroid filter into the optical train of the projector means a 50% to 60% loss of light on the screen, a further loss of light will be noticed by wearing of the viewing glasses. To overcome this light loss, it may be found necessary to replace the arc lamps and other projection equipment with higher amperage output appliances. A metallic screen will have to be installed, as the matte type of screen kills the illusion of depth. The loss of reflected light with matte types of screens is too great for use with third-dimension pictures.

An important point to take into consideration is the fact that all of the projection equipment was originally designed and constructed to take care of intermittent projection, a 20-minute period of operation and then a 20-minute period of rest. With three dimension projection the equipment will be in continuous operation, and it is possible that the equipment will not stand up under this usage. For instance, the generator was designed to carry the load for one lamp operation at a time, with a margin, for the time of carrying the second lamp while changeover was made. The generator will now have to stand the continuous drain of two arc lamps. The same applies to rectifiers. All of the projection and electrical equipment should be checked to see that it will stand up under these new operating conditions.

The introduction and switch over to these new systems is going to present many problems to both exhibitors and producers, other than those already mentioned.

If this conversion is done too rapidly, what is going to happen to the 300,000,000 dollars worth of film now on the producers' shelves and as yet unreleased? Producers will face a loss of income from the elimination of the foreign market, until such time as the foreign exhibitor can secure the new type equipment. This new equipment will have to be built in one of the sterling countries, Great Britain, Australia, New Zealand, India, South Africa are some of the countries doing business in pounds sterling. These countries, because of government restrictions, cannot import anything from any country where dollars have to be used in payment.

What is going to happen to the 3,500 Drive-In theaters in this country? What are they going to do for film product? Any system using the new expanded wide screen like Cinerama or Fox CinemaScope, which requires stereophonic sound, cannot be installed in Drive-in theaters, where they use the in-car individual speaker installation. It will be impossible to obtain directional sound with this type of speaker installation, and without the use of stereophonic sound with the expanded screen system a great deal of the illusion is lost.

Even with the third-dimension systems like Natural Vision, trouble is going to be encountered trying to adapt the systems for drive-ins. The illusion of depth falls off considerably as the viewing angle is increased. Those sitting in automobiles at the extreme ends of the ramps, viewing the picture through glasses, are going to see little if any of the third dimension. Even those in cars directly in front center of the screen, but in the rear ramps, will be located too far from the screen to get the depth illusion.

Another serious problem for the drive-ins will be the lighting of the picture. Most drive-ins today are using maximum light available from projection arcs. Further gain in light, by increasing the arc amperage, is restricted by the present limit of heat on the film at the gate aperture.

If these drive-ins cannot convert to third dimension, and producers in future concentrate on the making of third-dimension films, what are the drive-in owners going to do for film product? It has been proposed that one of the two films made for third dimension pictures be used to make the old flat type picture, and that these pictures can be used for drive-ins and the smaller theaters throughout the country. This, of course, can very easily be done, and it may solve the problem in places where the drive-ins and the small theaters have no competition, but what is going to be the reaction of members of the audience viewing some picture in two dimension, after seeing the same picture in the new third dimension?

Other problems will undoubtedly crop up before the conversion is made, but these should now be anticipated and answers found at the earliest possible date —these should be considered along with the question of standardization by the Motion Picture Research Council and the Society of Motion Picture & Television Engineers. Time is an important element in these discussions if we are to avoid the complicatons encountered back in the late twenties when sound was introduced.

WHAT IS IT GOING TO COST?

Let us here review this chapter to try and approximate the cost to the exhibitor for equipment and installation for the various systems.

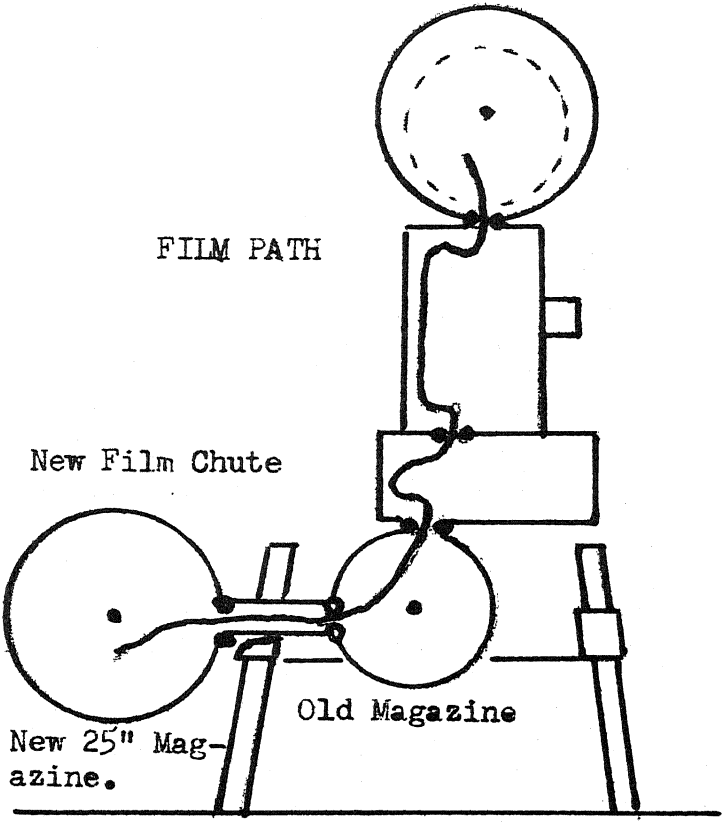
At time of writing, the only third dimension systems in use are those using two projectors for projection, and using glasses for viewing the screen picture. These are among others, Natural Vision, Tri-Opticon, Stereo-Techniques, all of these systems are now being sold exhibitors on a "package deal" basis.

The interlocking devices for the projectors, including the selsyn motors, the viewing glasses, the polaroid light filters for the projection ports, the oversized reels and film magazines, and the screen, are being supplied the exhibitor along with the film. The theater working on a percentage basis to cover everything, except the cost of the glasses that are used in viewing the picture.

How long this "package deal" will remain in operation, is not yet known, but sooner or later, exhibitors are going to have to purchase outright the equipment necessary for the showing of the third dimension pictures or the expanded screen pictures. What the cost is going to be for each theater, will of course, vary with the type of system decided upon, and just how much or how little of the present projection and electrical equipment will have to be discarded or replaced, and if the screen now in use will have to be replaced.

Another factor to be taken into consideration is the increased booth costs, not only for the projection staff, but for supplies like carbons, power etc. With systems where two projectors are used simultaneously, as with Natural Vision, light bills will double, the cost of supplies such as carbons will also double, projectionists salary will be twice as much, if the theater was previously a one-man booth. With two projectors running at the one time, two projectionists will be required for efficient and safe operation of the equipment. With these facts, the exhibitor can easily approximate his increased overhead.

Certain extra equipment will have to be added in the booth whatever type of system is decided upon, with the Natural Vision type of equipment, there will be the two extra oversized film magazines for each projector. In some cases the upper magazines may have to be of the "tilt" variety, to overcome excessive projection angles and allow clearance between the projector and the projection room walls. Manufacturers are now designing a 25'' diameter magazine for both upper and lower reels, these film reels are 23 inches in diameter so this will leave plenty of clearance for reels that are fully loaded with film. The magazines will also be made wider than the now three inches,



OLD TYPE W.E. UNIVERSAL BASE.

probably another $^7/_8$ of an inch will be added. A heavier gauge steel will have to be used in manufacturing these magazines, as the loaded weight for the reel on these new systems is approximately 28 pounds.

There is also talk of a change in the size of the diameter of the reel shafts from the present 5/16" to one-half inch.

The exhibitor will require four new magazines, besides a number of the large 23 inch reels. The cost of these film magazines will be known just as soon as manufacturers decide upon specifications and their manufacturing costs can be approximated; probably about $50.00 a pair.

One projector manufacturer has stated that the old ERPI Universal Projector Base cannot be used where these large oversize magazines are installed, and that theaters still using this type projector base will have to purchase a new base. However a rather novel suggestion has been advanced by our old friend Joe Cifre, of the Joe Cifre Inc. Supply House, of Boston, Mass. He suggests that the new oversized take-up magazine be installed at the rear of the projector, in the space that was originally used for the sound turntable. The film is threaded into the old takeup magazine through the fire-valve and an additional valve is cut in this old magazine, then through a film shute into the valve of the new 25 inch take-up magazine. This may be better understood by reference to the rough sketch, which Joe Cifre sent us with his suggestion. We understand that a great number of these old type bases are still in use, especially in New England, and this suggestion will probably be welcomed by the exhibitors in that territory.

In the Natural Vision system and other systems using two projectors running simultaneously, some form of interlock will be required, to keep the two projectors running in synchronism, during the projection of the picture.

Two forms of interlock are available or soon will be, these are the mechanical interlock, and the electrical interlock.

The merits of these respective types of interlocks is fully covered elsewhere in this book, the electrical interlock calls for the purchase of two new Selsyn motors to be used in addition to the two driving motors already on the projectors, together with other units making up the interlock system. The interlock will undoubtedly be sold complete as a unit. The cost will be about $500.00.

The mechanical interlock, which will also be placed on the market as a complete unit, will cost between $250.00 and $450.00, plus installation.

Other new equipment required will be polaroid filters and filter holders for each projector, polaroid viewing glasses for the projectionist etc.

A check will have to be made on the present electrical equipment such as generators, rectifiers, and arc-lamps, and the electrical wiring system.

Present day equipment was not intended for continuous operation, unless your present generator or rectifier is oversize, it may be necessary to replace these with higher output appliances. In regards to your generator, here is a thumb rule to use "The combined amperage drawn by both arclamps running on a continuous basis must not exceed 75% of the higher amperage rating of the generator." As an example, (1) If you desire to draw 70 amperes for each lamp, which means a 140 ampere continuous load, then the generator rated 100/200 amperes should be used, since 75% of 200 amperes is 150 amperes. (2) Should you desire to draw 80 amperes on each lamp for a total of 160 amperes continuously, then a generator rated 110/220 amperes will be required. Of course these figures only apply providing the generator is in good condition. If your present generator will not carry the necessary load for these new type equipments, then a larger generator will have to be installed, or an additional generator added. Your supply dealer can give you cost. In theaters using rectifiers, it will probably be necessary to replace these with larger rectifiers or a motor generator set may be more satisfactory. If a heavy duty continuous rectifier is now being used, then we suggest an additional rectifier be purchased, then these two can be run intermittently, one for the first hour of the show, the other can be used for the second half of the show. One cooling off while the other is in use. A 75-85 ampere rectifier will cost around $750.00.

The two arclamps in the theater booth have in the past been used intermittently, each lamp has been used for a period of say 20 minutes, then given a 20 minute cooling-off period, while the second lamp took over. With the Natural Vision system, and all other systems using viewing glasses, the two arclamps must now burn simultaneously and continuously for a period of approximately 55 minutes. These lamps were not designed nor intended for such usage, and it is just possible that they may not stand up under these new requirements. It would be as well to have your projectionist or your dealer check over this situation. Then again, arclamps drawing very high amperages are needed with these systems, extra amperage may be required at your arclamps, to help overcome the great loss of screen light entailed because of the use of the polaroid light filters in the booth, and the further apparent loss of screen brightness to the viewer due to the wearing of the polaroid glasses. If the required amperage is not now available with your present equipment, then the installation of new higher amperage lamps will be necessary. This will be a major item as regards expense as these high intensity lamps are costly, an 80 ampere lamp would sell at around $1,000.00.

One more item will have to be given consideration, that is the theater screen. Use of systems using glasses, require a highly reflective screen, if you now are using a matte (light diffusing) type screen, then this will either have to be replaced with a metallic screen or the surface of the screen will have to be treated with some metallic coating. This covers equipment necessary for all types of third dimension pictures in which glasses are used by the audience.

Now let us deal with CINERAMA. Frankly, we cannot see this system is going to find its way into any but the very largest theaters, and those only in the large cities. It can only be installed in theaters having a wide auditorium. No figures have been released as to the installation costs of the system now showing at the Broadway Theater in New York City, but it has been estimated that the cost runs between $50,000 and $100,000. Then again the overhead operating costs of the system make it impractical, except for these large city theaters, it requires the services of a minimum of four projectionists to run projectors and the sound controls. The overhead booth supply costs will be at least three times, and nearer four times, the cost of running a two-projector booth with the old flat type picture.

In many instances, theaters would have to have major structural changes to allow for the installation of the equipment. CINERAMA has caught the public fancy, it is undoubtedly a great box office attraction, and will prove so wherever it is shown, but this will, in all probability, be in a limited number of large theaters, situated in the larger cities throughout the country.

Another type of picture is that proposed by Fox and to be placed on the market under the name of CINEMASCOPE.

This is not a third dimension system, but an expanded screen type. The system calls for the use of a change in the standard screen ratio of 3 to 4, to one of about 2$^1/_4$ to 1, or maybe two and one-half to one. Calling for a screen between 50 and 60 feet wide. The wide picture is obtained from a single film, thrown on the screen by a single projector. The extra width is obtained by compressing the photographic image in making the picture, and then expanding this image, in projection.

The system calls for the installation of special expansion lens to be placed in the optical circuit of the projectors. These will be special made lenses and the cost will be relatively high. The equipment necessary for the showing of this type picture, will include, the special lenses, one for each projector, a special extra wide reflective screen, and the installation of a multiple speaker system, with speakers scattered throughout the auditorium as well as across the wide screen. In some of the publicity released by Fox the cost to exhibitors has been given as $2,500.00. To the writer this seems far too low, and probably by the time this book reaches the reader, a new figure will be made public. While only one projector will be run at a time, two projectionists will be necessary, one to run the projector the other for control of stereophonic sound. The extra wide screen picture, will also call for a higher arclamp amperage, which may require replacement of present equipment or the addition of new electrical equipment.

VISION

An elementary knowledge of the fundamentals of human vision, the action of light, and the construction and action of lenses is necessary for an understanding of three-dimension pictures, and also the expanded screen as proposed by 20th Century Fox.

Let us suppose a photograph of a human face and head, with its face and eyes directed straight in front so as to look directly at the speaker. Let a straight line be drawn through the tip of the nose, and halfway between the eyes, which we will call the middle line. On each side of this middle line there will be the same breadth of head, of cheek and of neck, and each iris will be in the middle of the whole of the eye.

If we now go to one side, the apparent horizontal breadth of every part of the head and face will be diminished equally; and at that position, however oblique, there will be the same breadth of face on each side of the middle line, and the iris will be in the center of the eyeball, so that the photograph preserves all the characteristics of a figure looking at the spectator, and must necessarily do so wherever the spectator stands to view the photograph.

Now, in the case of a real man, or any living object, one can generally tell in what direction the glance is directed by the appearance of the "whites" of the eyes. In a person looking straight ahead at anything, the pupil occupies the center of the eye, and if he still looks at the same object with the face turned a little to one side, the pupil no longer appears in the center of the eye, more "white" being seen on one side than on the other.

A moment's thought is not necessary to see how inconvenient it would be for one to lack the means of turning the eyes. The mobility of the eyes is absolutely necessary for the purpose of distance vision. The eyeball is worked by many muscles. It has a muscle to turn it heavenward, one to turn it earthward, another to turn it to the left and one to turn it to the right, besides two more of somewhat complicated action, six outside muscles in all for each eye. By outside we mean exterior to the eyeball. The top muscle is called the superior rectus, the bottom, the inferior rectus, the muscle on the nasal side of the eyeball is the internal rectus, and the remaining muscle the external rectus. When one looks upward the superior recti muscles are used, in glancing downward, the inferior recti muscles are used.

The axis of a body is a line with respect to which its parts are symmetrical, so that the axis of the eye is an imaginary line passing through the centers of the cornea, lens and eyeball. This line is generally called the optic axis.

We have stated that there are six outside muscles to each eye: four we have described; the remaining two are called oblique muscles, and they are employed to turn the eye on its axis, to make it rotate. This takes place unconsciously to ourselves whenever we incline the head to one side or the other.

We are now roughly acquainted with the external mechanism of the eye.

How is it that we can see an object a mile away as well, so far as its general form is concerned, as we can when the object is only a few feet away. It is apparent that if the inside parts of the eye were rigidly fixed the image in one case would be much more indistinct than in the other. In using binoculars we know that we must refocus the lenses when we change from a nearby object to one a mile away. Is the retina of the eye a movable screen or lens? When we change our gaze from the nearby object to one a mile or so away, do we unconsciously shift the position of the retina toward the lens in the eye? The images in each case are perfectly distinct, but it seems exceedingly unlikely that this distinctness is obtained by a shifting of the retina, for we know that the eyeball is filled with a jellylike substance. It is equally absurd to suppose that the lens of the eye is bodily shifted. The true answer is that the lens of the eye alters its form by making its front surface more or less convex, and by this means a perfect image is produced on the retina, whether the object gazed at be far off or near. In other words, the eye is focused by this procedure.

This change in the crystalline lens seems to be effected by means of a peculiar ring-shaped muscle, concentric with the iris. The outer edge of this ciliary muscle is attached to the same portion of the cornea as the inner margin of the iris. Whenever we look at a very near object, we contract this muscle, and this acts upon the attachments of the lens of the eye as to allow it to become more convex on its front surface; instantly the glance is transferred to a distant object, the ciliary muscle ceases to contract, and the eye lens is now pulled by its attachments into a flatter form. This device enables us, without being aware of it, to bring pictures of objects, whether near or far off, perfectly on the retina with the retinal membrane having to alter its position. We refer to this as focusing the eyes.

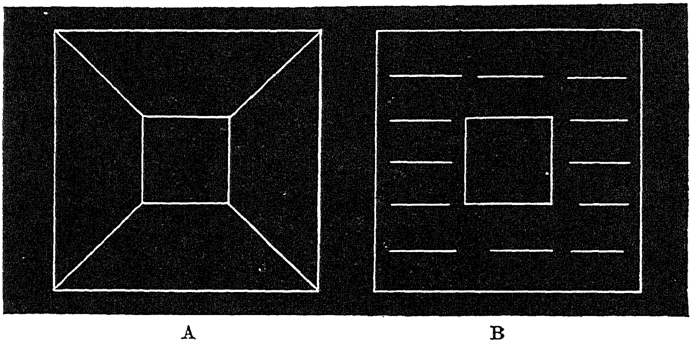
That the eyes have to be focused for objects at different distances is very evident, and can easily be proved.

Take two pencils and hold them in line, one behind the other. Hold one about nine inches in front of the eyes and the other about a foot further away, directly behind the first pencil. By no means can both pencils be brought into focus at the same time, if the first one is in focus the second pencil is blurred. If the eyes are focused on the second pencil, then the first one is blurred and indistinct.

The focusing of the eye has doubtless something to do with the perception of distance; for a certain state of the ciliary muscle and lens must always be associated with the idea of distance, while another state will never fail to be an index of nearness. Many other facts co-operate with these to give up a more or less perfect perception of distance, a very important one being the size of the image on the retina; the greater the distance becomes of an object from the observer, the less the image projected onto the retina. If the object remain the same, the greater the area of retina which is affects, the nearer we judge it to be to us; and conversely, the less the area of retinal nerve-matter it covers, the farther off we think it is.

Another important element in the perception of distance is the use of the outside eye muscles; for in looking at near objects we contract the internal recti muscles, and this action we come to associate with an idea of short distance, and the less amount of action the farther off we think things are, so that when the eyes are directed to a far-off object the very fact of our not having to use the recti muscles much in converging the action of the eyes, gives us the impression that the object we are staring at is a long distance away.

An act of mind alone, however, may give one the idea of nearness or distance, as can be proved with the following experiment:

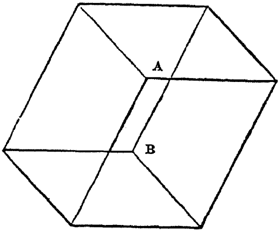


Illustrating the Action of the Mind in Judging of Appearance.

All parts of the illustration, figure A, are evidently in the same plane, but the inner square appears farther off or nearer than the outside square, just as one's mind thinks of it. If you think the inner square is farther away, you unconsciously call up the resemblance of a room with a square wall at the end, and the floor, ceiling, and the two sides sloping toward it; on the other hand, if you think the inner square is nearer to you than the outer square, it is because you think you are looking on a pyramid with its top cut off.

The source of the effect in each case are the converging lines which join the corners to the two squares. No effort of mind can remove the impression that in figure B the inner square is in the same plane as the outer square. Yet the squares in both figures are precisely the same size.

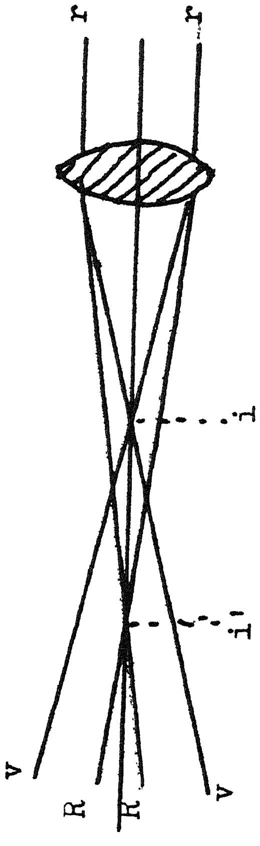
In the figure below, the angle A will appear either nearer or farther away, just as one regards the figure as leaning forward and a little to the right, or as leaning backward and a little to the right. The reader may have a little difficulty at first in realizing this, and it will be necessary to fix your eye on the point you wish to seem nearer, either A or B. Every part of the figure being in the same plane, it is evident that no muscle of the eye are concerned in this action. It is a mental action pure and simple.



The Illusive Appearance of a Geometrical Figure.

Our ideas of distance are founded largely on variation in size of the retinal image, and on muscular sensation. The artist, when sketching a scene wherein are many objects of the same size at various distances, puts them of different sizes in his sketch, to give proper perspective in the finished sketch. An artist in painting a picture can give the impression of nearness or distance by means of different colors, to give the impression of nearness he uses a fair proportion of warm red in the foreground, and uses a cold misty blue in the back. It was Prof. S. P. Thompson, who first came to the conclusion that the chromatic aberration of the eye accounts for the opinion of painters as to the "retiring" character of blues, and the "advancing" character of red tints. Let us examine these grounds of belief.

As a result of the chromatic aberration of the eye we know all the rays are not brought to a focus in the



The Chromatic Aberration of the Eye in relation to the Perception of Distance.

same plane. If the rays r r' be blue, they are brought to a focus at i; if the rays are red they are brought to a focus at i'. This can be proved by holding a silvered button in the sunlight, and looking at it through a purple solution of permanganate of potash, the button will appear either red or a bluish-violet, according as the eye was adjusted for the image i' or i. As a matter of past experience, we would think the light source producing i farther off than that originating i'. Thus the chromatic aberration of the eye, regarded as a serious fault, becomes an important element in the perception of distance.

An object with which we are perfectly familiar, and which we have felt and examined, has an image which covers a certain area of the retina. All objects at the same distance from the eye, whose images cover a larger extent of retina, we regard as bigger, and all with images less, we regard as smaller than the familiar thing we have compared them with. The image of a horse, for example, covers a larger area of the retina, than a dog the same distance away from the eye; the horse we conclude is the larger of the two. Our ideas of size are obtained by such comparisons, and in the representation of little known or rarely seen objects, we have to introduce familiar objects with which they may be compared. No idea as to the size of the Washington monument, could be formed, from a picture of it, unless we saw some familiar object alongside, such as men or animals from which to get our unit measurement.

Another defect of the human eye, known as "persistance of vision" is all important to a study of stereoscopic motion pictures, in fact without this defect in the eye, we would not be able to see the illusion of motion on the screen.

PERSISTENCE OF VISION

A very important phase of the research for perfecting the true representation of nature was to discover the means by which *motion* could be imparted to pictures.

The reproduction of motion is an accomplished fact, brought to a degree of perfection seldom equaled by any other discovery in the short lapse of time since its discovery.

Analysis and synthesis are the means by which the reproduction of motion is obtained, as they are the underlying factors upon which modern color photography is dependent.

Analysis by the resolution of movement into a series of secondary movements constituting a given whole is accomplished by photographic means, and synthesis by putting together the secondary movements thus obtained to form the whole desired movement, by means of projection.

This description of the essentials of moving pictures may seem rather abstruse but can be readily visualized.

Imagine the moving of an arm from a dangling position to an upraised one and consider this movement from the initial to the final position, as a *whole movement.* We can easily visualize innumerable intermediary positions that the arm is to pass through to reach the final one. As the whole movement of the arm is logically a continuous one the number of intermediate positions is infinite.

The problem that was faced by the researcher on the subject, was to find out how many of these intermediate positions were to be photographically registered, so that when viewed in rapid succession they would give to the eye the impression of continuous movement.

A well-known physiological phenomenon known as *the persistence of vision*, gave the answer.

When the light emanated by an object enters the eye an image is formed on the *retina*, which is a membrane of the eye that can be compared to the sensitive plate receiving the image formed by the camera obscura.

This retinal image has a certain permanency. It lasts for a short while before being cancelled by the succeeding image or by its natural elimination proper to the functioning of the eye.

This permanency or persistence of vision depends partly upon the intensity of the light that concurs to form the image, partly upon the intensity and character of the image that is going to supersede it.

Many are the examples that can be cited to illustrate the phenomenon of persistence of vision.

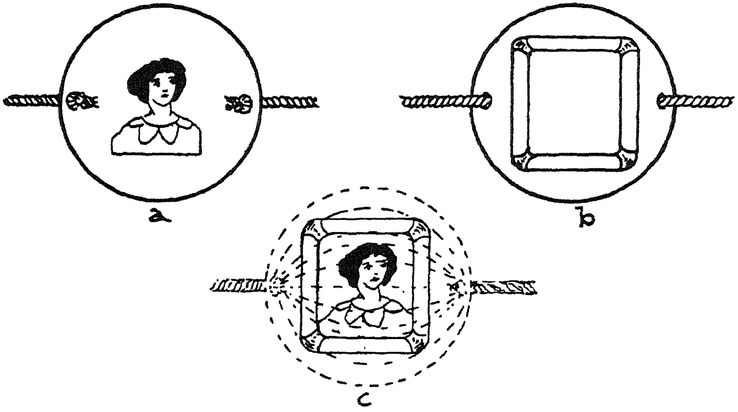
Falling drops of water look like uninterrupted water threads. In a rapidly rotated wheel, its spokes cannot be seen: but if the wheel is rotated in darkness and intermittently illuminated by sudden flashes of light, by means of a rapid succession of electric sparks, for instance, the spokes may be clearly made out. If a red hot piece of charcoal is rapidly moved about we see continuous streaks of light marking the displacements of the charcoal.

An amusing incident is often related on this subject.

In 1825, during an after dinner conversation, at which the eminent physicist Sir John Herschell was present, to amuse the gathering, Herschell asked if anyone in the audience could demonstrate how both faces of a coin could be seen at one time.

Someone suggested the holding of the coin in front of a mirror, but Herschell showed that the trick was possible by spinning the coin at a certain speed. Through the phenomenon of persistence of vision one face on the coin would make an impression on the retina of the observer before the impression of the other face had completely vanished.

This experiment led Doctor Finton, the following year, to construct a little, simple toy consisting of a round card on one face of which a cage was drawn and on the other face a bird. By spinning the card on its axis the effect was obtained that the bird appeared to be in the cage. This instrument was called the "*Thaumathrope.*"



Quite recently jewelry trinkets were in demand consisting of a gold disc on one face of which portions of a word or phrase were engraved and the remaining portion of the same word or phrase was also engraved on the other face. The disc was so mounted that it could easily be spun and by doing so the whole word or phrase could be read in its entirety.

Although the phenomenon was mentioned by Leonardo da Vinci, in 1472, it is quite impossible to fix with exactness the very beginning of the application of the persistence of vision to practical experiments or instruments. It is an historical fact that Newton, about the year 1670, proved his theory on the composition of light by pasting strips of paper of the colors of the spectrum on a cardboard disc, the dimensions and positions representing five spectra covering the whole surface of the disc. By rotating the disc by mechanical means the different colors blend and a uniform tint can be seen which changes according to the speed of rotation of the disc. When the disc is rotated at a certain high velocity the disc appears white thus proving that white light is formed by the fusion of all the colored lights of the spectrum.

Newton's disc proved the physiological fact that the impression on the retina always last longer than the stimulus (source of light) and that if a new impression is allowed to be formed before the previous is completely extinguished an impression consisting of the blending of the two is obtained and, furthermore, that several impressions can be made to react simultaneously on the retina. In the case of Newton's disc the seven colors of the spectrum, multiplied by five, represented thirty-five stimuli making an impression on the retina simultaneously.

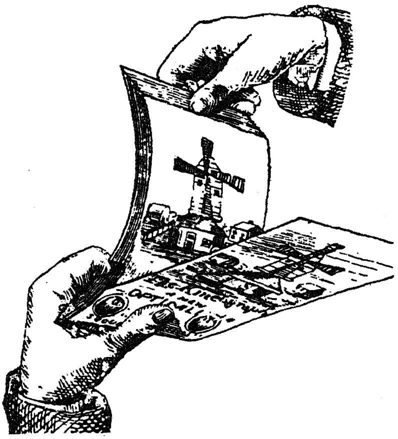
Plateau, in 1849, investigated the duration of the persistence of vision and although, as previously stated, it varies according to the intensity of the stimulus and to the sensitiveness of the retina, he placed it at as long as 30 seconds, as an average.

Further investigation proved that the impression on the retina is not immediate; it gradually increases until it reaches a maximum and then gradually decreases to disappearance, so when stimuli are made to react on the retina even in rapid succession, they quite harmoniously blend into each other.

The action of the retina is nevertheless extremely rapid and the normal eye can perceive a flash of light, such as an electric spark, having a duration of only 1/8,000,000 of a second. In such short duration the impression is not brought to the maximum ability of the retina to collect it, so that a light of low intensity, but long duration, makes a greater impression on the retina than a light of higher intensity but of extremely short duration.

In all apparatus dependent upon the phenomenon of persistence of vision the length of the stimulus must be sufficient to make its full impression on the retina and the intermittences must be of a duration sufficiently short to overlap the gradual decrease of the first with the increase of the second.

It has been established that the most efficient duration of the stimulus in the presentation of motion pictures with the average light intensity of the projection arc is of approximately 1/50 of a second with an equal interval of darkness. (Frequency 50.)



PERSISTANCE OF OPTICAL IMAGINATION

For years this theory of persistance of vision has been taken for granted by workers in the industry, and has served to account for the illusion of motion on the motion picture screen, it was left to Terry Ramsaye, in his book A Million and One Nights, to advance the theory which he termed "persistance of optical imagination" and we are giving you his word for word argument in favor of his theory.

"Ever since the first attainment of the projected film picture the simple statement of the principle of "persistance of vision" has been accepted generally as the complete explanation of the motion picture. That is too simple and easy to be true. After all, seeing a motion picture is something more and rather different from just piling one optical impression on top of another in the eye. True persistance of vision, or the holding of an image in the mind's eye until the next arrived to take its place, would result more likely in a jar between the successive phases of motion presented by the screen record. In rapid motions which are well portrayed on the screen this jar would be considerable."

"Following the researches of the experimental psychologists we must admit that the eye can only see what is there to be seen, namely a series of still pictures. The mind does not rest. By simile we may say that the screen shows the eye a row of dots and that the visual imagination makes a continuous line of it. We often, elsewhere than the screen, think we see motion where none exists. There assuredly is no motion on the screen."

"The successive still pictures of the object in motion appear merely to supply cues to an altogether mental process by which we build our impression of seeing it move. It would seem that there is something in our experience of seeing actual objects in actual motion which helps us to see movies, always in a forward direction. An exception to this progressively forward impression occurs in the common screen phenomenon of the wagon wheels which turn backward as the vehicle goes forward. On the strict theory of persistence of vision this would be impossible. It is possible only because the spokes are to the eye exactly alike and we can mistake a spoke behind in the progression of the wheel for the one we saw ahead. In other words, our mind gets a miscue because of the failure of the eye to identify. If our eye were so faulty as to confuse two actors we might get even more exciting results, but they would be of the same category."

"It is significant here that there is some evidence that we do not all see the motion picture alike. It was a common experience, when motion pictures were less common, to undergo a process of acquiring the conventions of screen seeing. The screen unquestionably offers a much more complete optical illusion to those who have grown accustomed to reading it.

"Let us analytically consider one foot of motion picture film, occupying one second of screen time in the theater (the 16 frames, one foot per second rate is based on the old silent picture rate), and calculate just how little the eye can actually see. It will give us a clearer notion of what a will-o'-wisp this motion picture illusion is. In exposing the negative for that foot of film in the camera, sixteen seperate and distinct individual pictures or snapshots of the subject are made. Under full illumination with the camera shutter aperture cut down, just as the amateur photographer speeds up the shutter in his Kodak to reduce light, these sixteen little snapshots may be exposed as briefly as one five-hundredth part of the second. This is a medium figure, exposures as brief as a five-thousandth of a second are possible if the light is strong enough. Now with the exposure one-five-hundreth part of a second our camera's eye is open to take note of the happenings before it, for only sixteen five-hundredths of the time our foot of film is travelling through the camera. This is a total of .032 of the total time."

"The camera makes note of what happens in sixteen instances of a five-hundredths of a second each. The camera is not recording what is happening approximately 97 per cent of the time. Yet when a positive print from the negative is presented in one second on the screen the spectator thinks that he sees what is going on continuously, all of the time. The spectator is only three per cent correct. It is not what we see but what we think we see that makes the picture. Pure persistence of vision does not explain that. Persistence of optical imagination is nearer the fact."

"It is interesting to reflect that assuming the same rate of exposure, one five-hundredth part of a second per frame of the film, a whole battery of cameras, say fifty, could be set up side by side to picture the same event in the same time and make as many entirely different records of it. If each camera was timed to expose in succession after its neighbor down the row, there would result fifty negatives, no two of which would be technically and literally alike. A foot of film from each camera would contain its sixteen snapshots made in a different series of five-hundredths part of the same second of time. All fifty negatives would be different, each from the other. Even more amazing, all of the total of eight hundred exposures included in the fifty one-foot negatives made in that one second would be different."

"Yet when each of these fifty pictures were projected on the screen they would all tell the minds of the audience the same story. No human eye could tell one picture from the other on the screen. The mind can put together eye-reported fragments amounting to three per cent and derive from that a sensation of seeing 100 per cent. The old saw about "putting two and two together" concerns a feat really trivial by comparison. We evidently believe a great deal more than we see. The eye reports facts but we see fancies."

LIGHT AND LENSES

"LIGHT is the agent or force by the action of which, upon the organs of sight, objects are rendered visible" and, as such, it is imponderable; it has no physical body which would permit our senses to ascertain its nature, but it has certain effects on them, especially on the organs of sight. Also it is the source of certain physical phenomena which permit the expression of hypothesis and theories which lead to an understanding of its nature.

Several are the known sources of light; heat, electricity, chemical combinations, phosphorescence. As light is the direct consequence of one of these causes, it is quite evident that through the cause a certain disturbance is created, a stimulus which is, translated into the capacity of performing a certain work, *i.e.*, into *energy,* which energy we call *light.*

Heat is one of the principal and most common causes of light. It has been ascertained that a non-luminous body, placed in the dark, begins to become visible when its temperature is raised 500 to 600 degrees and that its luminosity increases with the increase of the temperature.

Such body, then, does not create light of itself, but by submitting it to the action of heat, it provokes a very special disturbance which becomes manifest as light only when heat has reacted upon the body in a certain quantitative measure, and is subject to variations, according to the entity of this quantity.

The light emitted by the sun is the result of the extreme heat of its mass and of the state of incandescence of the vapors and gasses surrounding it. The temperature of the sun has been estimated at somewhat below 6,000 degrees Centigrade, nearly 11,000 Fahrenheit.

Thus light is a force which is created, so to speak, by physical or chemical causes; it is not a permanent state of matter. Being created, it has a beginning. The stimulus starts at its origin, the source of light, and it *must travel* to reach the eye. How and what makes light travel has been one of the very first questions that Science has tried to answer and to this day no positive answer has been made but the investigations carried on have given rise to theories or principles and suppositions which have received a certain confirmation as to their validity for they explain the phenomena pertaining to light.

Bodies are called transparent or opaque according to their faculty of permitting light to go through them, or by checking its course. In both cases some readily seen, and, thus measurable, phenomena happen.

When light encounters a transparent body, for instance, it is always deflected from its course and this deflection is constant for any portion of the same body and is always of the same order for all transparent bodies. This deflection of the light is then subject to some physical laws which have been ascertained to be always governing the passage of light from one transparent body into another.

Likewise when light strikes an opaque body it rebounds and is reflected and the reflection is always subject to other laws from which it never deviates.

Other phenomena pertaining to light are also found to be regulated by innumerable physical laws.

It is the study of these phenomena, the discovery of their effects, functions and governing laws which have been investigated and measured with great accuracy, and the relationship that has been found to exist among themselves and with regards to other fundamental laws regulating other physical phenomena such as *heat* and *sound,* has permitted science to promulgate the above mentioned theories and to sustain them by applying them to the explanation of all such phenomena.

THEORY OF LIGHT PROPAGATION

There are innumerable evidences that light is propagated in a straight line. A beam of sunlight entering a dark room through an opening in the shutter of a window forms a sunspot on the opposite wall or floor of the room and this spot marks the continuation of the imaginary straight line joining the opening in the window and the sun. The shadow cast by an opaque body makes a straight line with the body and the source of light, thus it can be stated that light travels in a straight line. As stated previously, light originates from a source, light then must travel with a certain velocity.

It was at first thought that light was propagated by matter carrying the light energy. This gave rise to the *emission* or *corpuscular* theory. This theory, sponsored by Newton, implied the existence of infinitesimally small corpuscles which were shot, so to speak, from every point of the source of light in uninterrupted succession and in all directions at a great velocity. These corpuscles by impinging on the eye would provoke the sensation of vision.

Newton explained all known phenomena of light by the emission theory, but its truth was contested by Huygens, a contemporary of Newton, on the grounds that the emission theory implied an increase of velocity of the corpuscles when traveling through substances heavier than air. This was denied by Huygens and many years later was proved erroneous by Faucault, while investigating the velocity of light. In Newton's time the emission theory held good in spite of the great attention and interest paid to Huygens' disclosures.

According to Huygens, light was not propagated by matter carrying the energy, but this energy alone was transmitted as a wave motion through stationary matter.

This theory implied the existence of a medium by virtue of which the light waves would be propagated.

Huygens in his theory surmised the existence of an extremely elastic fluid of infinite tenuity, filling all spaces and all matter.

fill all spaces in the universe. The ether must exist in the interstellar spaces beyond the earth's atmosphere, so as to permit the light energy emitted by the sun and the stars to reach the earth, as well as it must fill the infinitesimally small interstices between the molecules of all substances from the lightest gas to the heaviest metals.

Each point of a light source is supposed to become the center of a disturbance creating a spherical system of waves, which thrown into the ether travel at a velocity first calculated by Roemer to be approximately 186,000 miles per second.

Each point of this spherical system is supposed to become itself the center of a disturbance and thus create its own system of secondary waves, thus forming an unlimited complex of spherical systems of waves within a sphere, whose center is the luminous point. The outmost boundary of the main sphere is called the front wave.

Huygens presented his theory at the French Academy of Sciences in 1678 and through it gave a physical and mathematical explanation of nearly all known phenomena pertaining to light. The theory received the appellation of *undulatory theory* due to the undulatory progression of the waves.

Newton challenged the truth of the undulatory theory in favor of the emission theory because Huygens could not satisfactorily explain the rectilinear propagation of light.

In later times, Fresnel, (1802) succeeded in proving the approximate rectilinear propagation of light by the wave theory and in expressing such a thorough explanation of the phenomenon of diffraction that it proved the ultimate argument in favor of this theory. The emission theory was then entirely discarded.

Fresnel admitted the existence of the *luniniferous ether* stating that its density is constant within the same substance or medium but varies from medium to medium and, by considering the light waves as elastic waves, such as those visible in a taut cord set to vibrate, he could establish the law that the velocity of light in any medium is inversely proportional to the square root of the density of the ether inside that medium.

In the year 1865, Clerke Maxwell expressed the *electromagnetic* theory of light, based upon the relation he discovered to exist between the specific induction capacity of the *dielectrics* (non-conductors of electricity) and the influence that these substances have on the velocity of light traveling through them.

Clerke Maxwell tended to prove that the medium in which luminous and electrical actions are transmitted, is the same, and that there is an impulsive power, or motion as well as energy in the light waves.

The velocity of light in air was calculated by him by purely electrical means and he gave the result as 299,300 kilometers per second as compared with the mean of 299,800 kilometers obtained by direct observation.

This remarkable result led Maxwell to state that light is an electromagnetic wave and, although he succeeded in calculating the pressure exerted by the momentum of the light waves, he could not prove the existence of the electromagnetic waves.

His reasoning was purely mathematical and as no phenomena could be explained by the electromagnetic theory that could not be explained by the undulatory theory the former was little considered until Hertz, from 1888 to 1892, proved that magnetic intensities are propagated at a measurable and thus finite velocity and succeeded in producing and giving proof of the existence of electromagnetic waves.

Since Hertz disclosures, the electromagnetic theory obtained great favor in the scientific world, but as the undulatory theory can still be used in treating of the phenomena of light that are of interest to the readers of this work and in a more intelligible way, as it avoids the mathematical calculations involved in the Maxwell theory, we will not depart from it.

LIGHT WAVES

The acceptance of the undulatory theory involves the existence of waves, propagating the energy emitted by the luminous body.

The simplest example of wave motion is that of the vibrations imparted to a taut string. If a shock is produced at one end of the string the whole string is set into a vibratory motion which from its start, at the point where the disturbance is first created, is propagated to the other end and is continuous, until the influence of the distrubance ceases to have effect and the string is again in a state of rest.

It is seen that the string is not displaced and that the waves are formed by a change of position of each of the points of the string. Their propagation is very similar to the propagation of the waves created on the surface of stagnant water by any disturbance.

The appellation waves is applied to all disturbances in which a particular state of a medium is brought on without change in the medium and it originates from the familiar effect of waves produced on the surface of water.

Suppose that a cork is lying on the surface of a calm pool and the surface of the water is touched at any other point by means of a stick or by throwing a pebble into the pool. A circular system of waves will be formed having as center the point of disturbance. These waves will have a *transversal* motion and gradually enlarge their circle, the extreme boundary of which will at any definite time mark the *wave front* of the disturbance. When these waves reach the cork the latter will be seen to follow the transversal motion but to remain in the same spot. Light waves are propagated in a very similar manner.

The length of the light wave has a marked influence on the quality of the light, as waves of different length have a different repercussion upon the eye and establish the different sensations called colors.

As the light waves are propagated with a finite velocity it is easily understood that other quantitative entities can be expressed and this in respect as to time and space.

The first of these entities is the number of waves that are created in a certain fixed time. This has been called the *fre-*

quency and the time has been fixed to a second.

The second entity is the number of waves contained in a certain fixed distance between two points of the train of waves. This distance has been fixed to the centimeter and the attribute is called the *wave number.*

LUMINOUS AND NON-LUMINOUS BODIES

All bodies can be divided into two classes, *luminous* and *non-luminous.* As we have stated bodies become luminous under the influence of some action of physical or chemical order. A body is then said to be luminous when this influence is acting upon it and is thus creating the light energy.

Bodies in the non-luminous state are said to be *transparent, translucent* or *opaque.* Substances that readily permit the transmission of light and through which objects may be seen are called transparent. Gases, clear water, polished glasses are transparent bodies. Substances which transmit light, but through which objects cannot be distinguished, are called translucent. Ground glass, porcelain, etc., are translucent.

Substances which do not permit the transmission of light are called *opaque.* Metals, wood, stone, etc., are opaque bodies.

There are no perfectly opaque nor perfectly transparent bodies. Consider, for instance, water as a highly transparent substance. A sufficient thickness of water, no matter how pure it may be is quite impenetrable by light and, on the other hand, when gold is reduced to a very thin leaf, it transmits a green light.

It is quite evident that if an energy or force propagated by a constant motion in a certain definite direction meets an obstacle in its course something is bound to happen. When a rubber ball is thrown against a wall, it rebounds from it with a speed almost equal to the speed imparted to it by the thrower. A stone thrown against the same wall also rebounds from it, but at a speed greatly less than that of the rubber ball. If a stone is thrown into water it goes through the water but its speed is lessened.

When the light energy meets an obstacle in its path, similar phenomena happen and the study of these phenomena and the laws governing them are part of that branch of physical science called *optics*.

LIGHT RAYS

All luminous bodies create the energy called light and this energy has been shown to be propagated in all directions. It is quite evident that this energy presents the same properties at every point where it is propagated. The light energy emitted by an electric bulb placed in the center of a room has the same characteristics in all corners of the room and if it is desired to learn some of the intrinsic properties, it will be sufficient to investigate them at any one point of the room. It was thus found necessary to establish a minimum entity of light energy, the knowledge acquired on its behavior standing good for all other similar entities of the same source of light.

As light is propagated in a straight line we can imagine *one definite point* of the luminous body creating the light energy and from this point the portion of this energy which reaches another point at any distance from it. This quantity of light energy receives the name of *ray*.

A ray of light is then an imponderable entity of light representing the direction in which light is propagated.

When the light of the sun is permitted to pass through a small orifice drilled in the wall of a dark chamber and the chamber is filled with a thin cloud of smoke a streak of light is made visible which is commonly called a ray. This streak, in fact, no matter how small the orifice may be, is composed of an infinite number of rays. Such an agglomeration of light rays is called a *beam* or *pencil of light*.

The path of a ray of light in any substance can be followed with great precision and a visual representation of it can be drawn on paper.

White light is formed by the amalgamation of lights of different colors. The lengths of the wave of the colored lights differ among themselves and their behavior varies in accordance with the nature of the transparent body they are traversing. It is then necessary not only to consider the segregation of a single ray of light, but also the segregation of a ray of a certain wave length.

WHEN a ray of light impinges upon the highly polished surface of an opaque body the greatest portion of its light rebounds into the medium in which it was traveling, and it is said to be *reflected,* and a small portion of it is absorbed by the opaque body.

Some of the reflected light follows a definite path in obedience to definite laws and it is said to be *regularly reflected;* some is irregularly reflected and it is called *scattered light.*

All opaque bodies absorb and reflect light and it is through the phenomenom of irregular reflection that they are made visible. The light that is regularly reflected gives us the image of the luminous source, while the light that is scattered in every direction from every point of the reflecting surface acts upon the eye as if each one of these points was a light source, and, therefore, forms their image in the eye.

The ray of light impinging upon a reflecting surface is called the *incident ray* and the ray that rebounds from the surface is called the *reflected ray.*

The regularly reflected ray of light, follows two laws which are expressed as follows:

I: The angle of reflection is equal to the angle of incidence.

II: The incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.

The truth of these laws can be proven by several physical experiments, the best known and the one which is perhaps the most susceptible of great accuracy is as follows:

A small telescope is set upon a graduated disc which is placed in a vertical position. The telescope is aimed at a plainly visible star and its position is read on the scale of the disc which corresponds with the optical axis of the telescope. A vessel filled with mercury is placed at a suitable distance from the telescope. From its former position, the telescope is aimed at the image of the star reflected by the mercury. A reading is also taken on the graduated disc and it will be seen that the two lines drawn from the center of the axis of revolution of the telescope to the readings obtained from two equal angles with the horizontal passing through the same center. An elementary geometrical construction proves that the angle made by the light rays of the star with the normal to the mercury surface is equal to the angle made by the reflected light with the same normal.

The second law is proved by the arrangement of the apparatus itself.

INTENSITY OF REFLECTED LIGHT

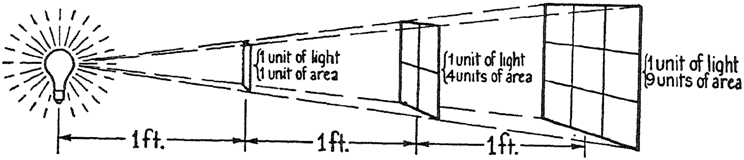
It is quite obvious that, due to the partial absorption and scattering of the light propagated by the luminous body, the intensity of the reflected light is *less* than the intensity of the incident light.

The intensity of the reflected light is also dependent upon the nature of the reflecting surface, its degree of smoothness and upon the obliquity of the incident ray.

The power of absorbing light varies with different substances and this influences the visual brightness of each substance as well as the intensity of the light reflected by them. The highly polished surface of a silver mirror reflects more light than the equally smooth surface of a sheet of paper.

If a reflecting surface is very coarse, it presents to the incident light a great number of small surfaces under an infinite variety of angles and consequently the reflected light is so divided by reflection in so many directions that its intensity is much less than the intensity of the light which would be reflected by a highly polished surface of the same substance.

Less commonly observed but easily verified is the influence exerted upon the intensity of the reflected light by the obliquity of the incident ray in respect to the reflecting surface. If we stand on the shore of a large body of water, such as a tranquil lake, we can readily observe that at high noon when the sun is approximately at the zenith we can look at the water without being disturbed by any glaring reflection. As the sun nears the horizon the reflected light becomes stronger and stronger till in the late part of the day the light glare from the water is so intense that the eye can hardly look directly at it.



The level of illumination varies inversely as the square of the distance from the light source to the surface

REFRACTION OF LIGHT

When a ray of light which is being propagated in a medium of a certain density encounters a transparent medium of a different density it passes through it, but its course is deviated. This phenomenon is called *Refraction.*

The light that is refracted is as in the case of reflection, of less intensity than the incident light, due to the fact that a small portion of it is reflected by the boundary surface, some of it is scattered and some of it is absorbed by the refracting medium.

It has been stated previously that Foucault has proved conclusively that light suffers a diminution of its velocity when passing from a medium of certain density into a medium of greater density.

This diminution of velocity is due to a constant dying away of the light waves while they pass through such dense medium and their constant replacement by new waves.

The dying away and replacement of waves results in a retardation of their velocity.

A group of waves moves at a lesser speed than the individual wave and its speed is inversely proportional to the density of the medium.

The change in velocity is cause of a change of direction of the light ray and this change of direction takes place at the surface of the second medium. From this surface the light travels in a straight line throughout the medium, providing the latter is homogeneous.

WHENEVER an object which is either luminous or is stricken by light emanated by a luminous body is presented to the eye the radiations that it emits as in the first case, or the ones that it reflects, as in the second case, produce the sensation of vision and the object is said to be seen.

When the rays emanated from the object enter the eye they suffer a series of refractions and an *image* of the object is formed upon a very sensitive membrane in the eye called the retina and is transmitted to the brain by some quite unknown physiological and psychological processes.

The image of the object is a reproduction or counterpart of the object itself, or better, a reproduction of each and every one of the points of the object from which a ray of light is emitted so it may reach the eye without encountering any obstruction in its path.

The image formed upon the retina is a purely physical one and the conditions necessary for its formation and for the formation of similar images have been known and studied for several centuries.

When an image is formed by a suitable combination of lenses so that it can be collected upon a screen, each point of the screen radiates reflected rays of light of different intensity and color, according to the rays forming the image itself, and if the eye is so placed as to receive these rays it will form on the retina a counterpart of the image and therefore a counterpart of the object itself. The impression is then the same as if the eye was looking directly at the object.

If the image is collected on the screen so as to make a permanent impression upon it, and this is indeed the case in photography when the sensitive plate or film acts as a collecting screen, such image is revived into the eye at any time its gaze is directed upon it.

It is obvious that the image formed upon the photographic plate or film must be as similar as possible to the object photographed in order to transmit to the mind the impression that the onlooker is looking at the object itself.

The formation of such perfect image involves many optical problems and considerations.

PIN HOLE IMAGES

It has been previously stated that an object emits very definite radiations from each of its points and that these radiations travel in a straight line. It was also said that the camera obscura is an instrument by means of which images of objects can be collected upon a screen.

The formation of images in the camera obscura is the simplest example of such phenomenon and its explanation will serve as guide in the study of image formation by optical instruments.

If we theoretically suppose the orifice of the camera obscura small enough to permit the passage of only one of the several rays of light emitted by a given point of the object we can visualize that only this one ray concurs to form the image of the object point on the wall of the camera obscura opposite to the opening and only one single ray from each point of the object will enter the camera obscura and strike the wall in such position that a complete image of the object is formed on it.

Let us consider the line $l\ l'$ as representing the object; o the small opening in a wall of a darkened room and s a screen upon which the image of the object is formed.

The point *l* of the object emits rays in all directions but only the ray *l s* enters the instrument due to the extreme smallness of *o*. This ray will then impinge upon *s* on the screen and can be viewed either by reflection, by placing the eye at any place in front of the screen or by looking at it from points behind the screen if the screen is translucent.

The ray *l s* in the figure is perpendicular to the opening and it marks the position of the imaginary line called the *Axis*. The point *o* on the axis becomes the meeting point of all the rays which, coming from the object are admitted through the opening into the camera obscura. Therefore, if two other object points are considered, such as *l* and *l′* we can easily understand that only one of the rays emitted by these points will pass through *o* and impinge upon the screen at the points *s* and *s′* respectively. Every point of the object placed in front of *o* will then transmit one single ray through the opening and each one of them will strike the screen at a point dependent upon the inclination of the ray in respect to the axis.

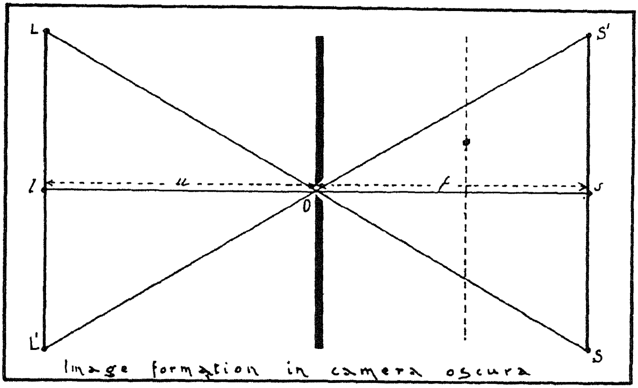


Image formation in camera oscura

Each object point will, therefore, have its corresponding image point on the screen. Two such similar points are said to be conjugate points.

Let us consider the line *l l′* as representing the object; *o* the small opening in a wall of a darkened room and *s* a screen upon which the image of the object is formed.

The point *l* of the object emits rays in all directions but only the ray *l s* enters the instrument due to the extreme smallness the dotted line, an image will be formed at this new position, but its size will be found to have varied.

It is evident from the figure that the closer the screen is to the opening the smaller the image and vice versa the greater the distance of the screen from the opening the greater is the size of the image.

If the screen is kept stationary and the object is set nearer or further away from the opening, the size of the image will vary accordingly and be greater, the closer the object is to the opening.

It is quite obvious that, due to the geometrical construction of the figure some definite relation exists between the size of object and image in respect to the distance between them.

The ratio between the size of the image and that of the object is called the *magnification* and is denoted by the letter *m*.

The distances from the object to the opening and from the image to the opening are measured along the axis and are respectively called the *object distance* and the *image distance,* the first being denoted by the letter *u* and the second by the letter *f*.

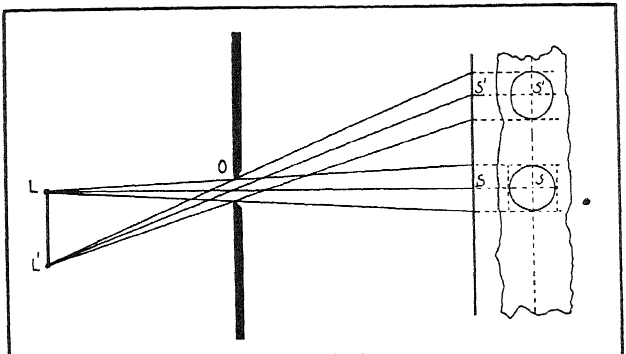
The perfect understanding of these relations between object and image size and distances will prove its value in the study of images formed by lenses and lens systems.

The pin-hole opening has been this far considered as small as a theoretical ray of light.

In actual practice, such smallness is unattainable so that the opening of a camera obscura always has a certain area and a bundle of rays originated by each object point will enter the camera obscura instead of the single ray previously considered.

Another factor has to be taken into consideration in the investigation of the size of the pin-hole opening. When a pencil of light is partially intercepted by a keen edge or is made to pass through either a narrow slit or a small opening the phenomenon of *diffraction* takes place.

If the pin hole of the camera obscura is so small that diffraction is provoked, the sharpness of the image is greatly impaired. A lack of definition will also be the result from a pin hole of too great an area.



Sharpness of a pin hole image

Let *o* be the orifice of the camera obscura, *l l′* the object and *s s′* its image. The pencil of rays emanated by the object point *l*, which may enter the orifice *o*, assumes a conical form and therefore, instead of producing at *s* the exact image of the point *l* it produces a circle, the size of which is dependent upon the size of the opening and the image distance. The axis indicates the path of the *principal ray* and the center of the circle while the marginal rays will trace the circumference of the circle.

If the size of the opening is so calculated that it is as small as possible without creating a disturbing amount of diffraction this small patch of light will then represent the best obtainable image of the object point *l*.

The same reasoning applied to the object point *l′* proves the formation of a patch of light at the point *s′* of the screen, which is the best obtainable image of the object point *l′*.

The circular shape of the patch will be altered into an oval shape the farther the image of the object point is from the axial point *s*. The image of the central point will thus be sharper than at any other point of the image surface, this sharpness gradually diminishing the farther the image point is from the center *s*.

The patches of light thus formed are called the circles or discs of confusion and it is quite evident that the sharpness of the whole image is dependent upon the size of these discs.

RESOLVING POWER OF THE EYE

The unavoidable formation of the discs of confusion would make it impossible to obtain images of sufficient sharpness if the eye had the power to distinguish their existence at the smaller size that diffraction permits.

But the eye does not fortunately possess such a keen power of separation.

If two lines are drawn on a sheet of paper very close and parallel to each other and are looked at while the paper is moved away from the eye, a certain distance will be found at which the eye fails to distinguish any separation between them, and the two lines blend into each other and appear as one. Two points will, under the same conditions, also appear as one.

The power that the eye possesses to distinguish two separate lines or points is called the resolving power of the eye.

There are many factors which control the resolving power of the eye, such as the size of the two points in respect to the distance separating them, the intensity of the light under which they are viewed, the contrast existing between the points and the spaces of separation and so forth.

All these considerations waved aside it can be stated as a general and elastic rule that the eye has the power to resolve two points when these are at a distance apart which subtend a visual angle greater than one second or 1/60 of a degree.

Suppose the two points placed at *a* and *a′* to be such a distance from the eye *e* that the angle *a e a′* is the resolving angle. The two points *b* and *b′* set at a greater distance from the eye, must be further apart from each other to be still distinguished by the eye as two separate points.

Several practical experiments will demonstrate the phenomenon.

Suppose a street lined on one side by a series of brick buildings. If we look up the street we clearly distinguish on the nearby buildings the lines of separation of the bricks, especially if these are held together by white mortar. The further the buildings are from the eye the more difficult it is to distinguish the separation and at a certain distance the walls of the buildings will appear of a uniform red hue.

Leaves of trees are perfectly discernible from a certain distance but such distance can be found at which the whole tree will appear as a mass of green and the leaves will no longer be distinguishable.

A roughly plastered wall will appear as a smooth surface if looked at from a certain distance and so forth. Many examples can be cited even to those involving such great distances as the interplanetary ones.

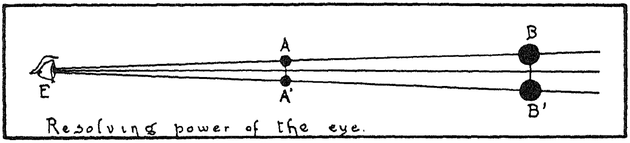
Two stars, for instance, may be at a tremendous distance from each other and yet will appear to the naked eye as a single luminous point. The plurality of stars can only be determined by the use of powerful telescopes.

Although the distance between two stars may be several millions of miles the still more enormous distance at which they are from the earth makes their separation to be within the angular limit at which the eye loses its resolving power.

It results that if the discs of confusion which concur to form an image are sufficiently small so that they do not impair the fine details of the subject enough for the eye to resolve such impairment, the lack of definition which is caused by the discs will not be detected by the eye and the image will appear *sharp.*

The circles of confusion are not separated from each other but overlap throughout the whole image surface and therefore it is seldom, if ever, necessary to have recourse to the very smallest obtainable disc of confusion for obtaining a so-called perfectly sharp image.

The smallness of the opening of the camera obscura limits to a great extent the quantity of light that is admitted into it and therefore the luminosity of the image is extremely low, but the image presents the great advantage of being a perfect reproduction of the object as to ratio of sizes and therefore as to perspective. Also, if the object is composed of several planes succeeding each other, as is the general case in any landscape or scene, all the different planes are imaged upon the single image plane with the *same degree of sharpness* or, in other words, with an *infinite depth* of focus. Thus the camera obscura may be said to give undistorted ideally true images



Resolving power of the eye.

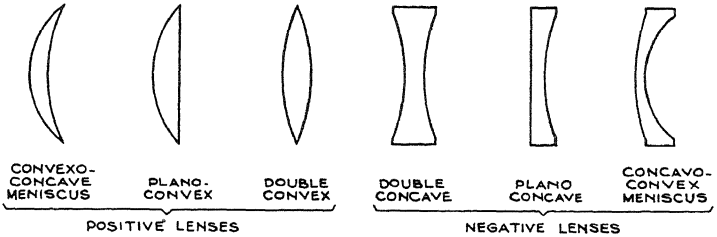
These attributes of the camera obscura have been put to good use in laboratory experiments where the trueness of the image is more important than its luminosity and also in the reproduction of subjects such as architectural motives, where the absence of distortion and the rendition of true perspective are essentials.

THE virtual images formed by mirrors for the very fact that they cannot be collected upon a screen, cannot provoke the chemical changes in the photographic emulsion which are the cause of the permanent photographic image.

The real images formed by mirrors are used in photographic procedure only in special cases which lie far beyond the scope of this book and have not found as yet adaptation in practical cinematography.

The image formed by the camera obscura, is a real image because each small pencil of rays which is admitted through the pin hole opening, actually strikes the surface of the screen. If the screen is a sensitive plate or film, it will be affected by these pencils of light and the photographic permanent image of each and every point of the object may be obtained.

The image formed by the camera obscura has been said to have such a low luminosity that a great amount of exposure is necessary for the sensitive emulsion to undergo the changes which produce the photographic image.



The limitations imposed by the lack of sufficient illumination of the image obtained by a pin hole are overcome by the possibility of converging to one point in an image plane situated behind the optical system, a great number of rays emitted by one object point.

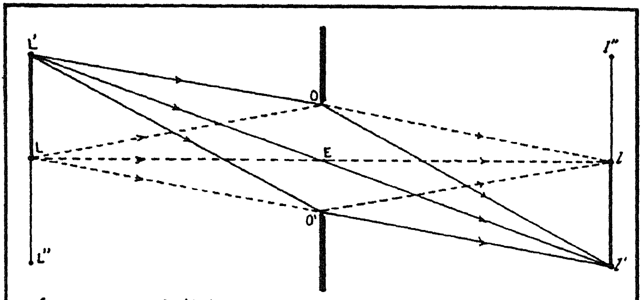
The figure illustrates the condition of convergence which the light rays shall answer to bring forth the increase of illumination of image-points.which is highly desirable.

The aperture *o o′* which admits the light rays, being greatly enlarged, it results that the great number of rays emanated from an object point *l* for example, and made to pass through the aperture would not form an image unless they are made to converge so that their paths are directed towards one single point in the image space and form there a conjugate focal point of the object point *l*.

This effect is obtained through the phenomenon of refraction and by the use of convergent lenses or systems of lenses.

A lens is a piece of refracting material, most usually glass, by which the path of the light rays may be controlled by means of both the quality of the material of which the lens is made and the shape of the refracting surfaces which serve as the boundary of the lens.

By tracing the path of at least two of the rays emitted by an object point situated either on the axis of the lens or outside of it and passing through the refracting system, we should, in order to obtain a perfect image of the object point, find them to converge at exactly the same point in the image space where a conjugate of the object point would therefore be formed. In other words a perfect image of that object point should be formed by the meeting of the refracted rays and such image would be much more luminous than the image of the same point of the same object obtained through a pin hole, because of the concentration of a great number of light rays instead of the direct effect produced by the rays of the extremely small pencil of light limited by the size of the pin hole.



Convergence of light rays concurring to form an image

This would be the ideal condition under which an object, occupying one plane perpendicular to the axis of the lens, would be reproduced in an image plane. In reality many factors enter into play, which concur to diminish the trueness of rendition of such image.

POSITIVE CONVERGENT LENSES

Three distinct kinds of positive convergent lenses may be defined according to the characteristic form of the lens.

The most distinct characteristic of convergent lenses is that they are thicker at the axis than at their edges. Recalling the path followed by rays refracted in convergent lenses this characteristic proves to be essential to provoke the convergence of the refracted rays.

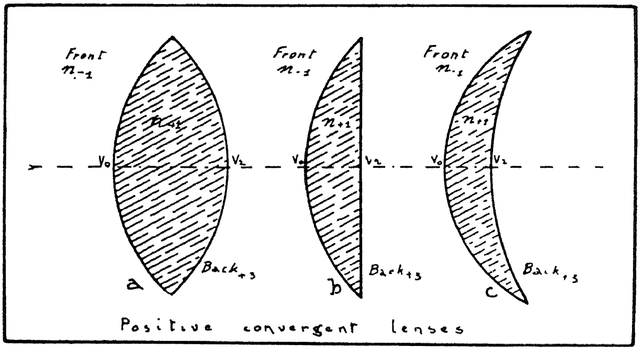
Lens *a* is called *biconvex* because both of its surfaces are convex or bulging outwards. The radii of curvature of the lens illustrated in the figure are equal for both faces of the lens but it is quite evident that the surface of a biconvex lens may have radii of curvature varying in length. An infinite variety of such lenses may therefore be designed each one of which will have its proper power of convergence.

Lens *b* is called a *plano-convex* lens because one of its faces is convex while the other is a plane perpendicular to the axis. The plane surface may be considered as a portion of a sphere having a radius of an *infinite length* while the other face may have a radius of any desired *finite* length.

Lens *c* is called a *convergent meniscus* because of its crescent-shaped form. Again the radii of curvature of the two faces may be equal to each other or vary in length at the will of the designer.

Since the investigation of the path of the light rays through the different media is fundamental in the designing of optical instruments and, therefore, essential for the understanding of their functions, it has been found necessary and convenient to establish a notation with reference to the points, angles, surfaces and distances whose determination is essential for the calculation of the path of the rays which concur to form the image.

Conventional symbols and signs have been adopted, some of them internationally used, such as the symbol *f* to denote the principal focal point and the signs + and — to indicate the positive or negative characteristics of the values under consideration; other symbols and signs have obtained a less international recognition and are indiscriminately used by the different investigators.



Positive convergent lenses

NEGATIVE DIVERGENT LENSES

Although divergent lenses do not form real images and are, therefore, unsuitable for photographic purposes if used alone, they pay an essential rôle in combination with positive lenses as it will be seen later.

As in the case of convergent lenses, three distinct kinds of divergent lenses may be defined according to the different combinations which can be obtained with hollow curved surfaces.

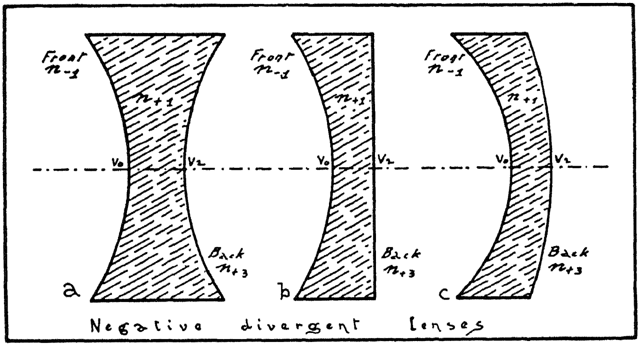
The main characteristic of divergent lenses is that they are thinner at their centers along the axis than at their edges, in opposition to convergent lenses the characteristics of which are diametrically opposite as has been shown.

Lens *a* is called *biconcave* because both of its faces are concave, that is they are both part of hollow spheres. The radii of curvature of the two faces may be equal in length or they may be of different magnitude and it is then evident that by varying the radii of curvature the power of divergence of the lens may be controlled at will.

Lens *b* is called a *plano-concave* lens, one of its faces being concave and its radius having any desired finite length while the other face is a plane and can, of course, be considered as a curved surface having a radius of infinite length.

Lens *c* is called a *divergent meniscus* because of its similarity to the crescent shaped moon. Its faces are both curved surfaces and may have any desirable finite radius of curvature.

The same notations used in connection with convergent lenses apply to divergent ones and the symbols and signs in the figure do not require any further explanations.



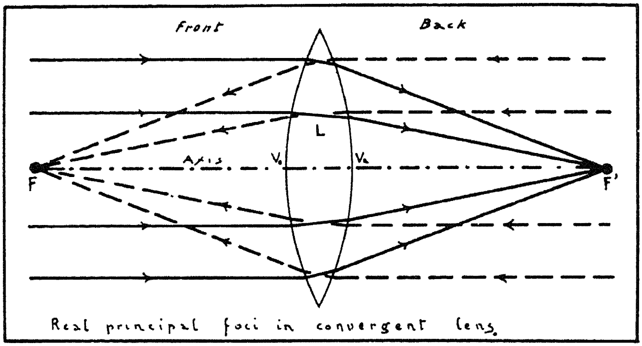
Negative divergent lenses

FOCAL POINT OF LENSES

The points to which converge the luminous rays emanated by a single object point after refraction through a convergent lens and the points created by the imaginary prolongation of the rays refracted by a divergent lens are called the *foci* of the lens.

As in the case of mirrors, *principal* and *conjugate* foci are formed according as the rays emanated by the object are parallel to the axis or inclined to it.

Paraxial rays parallel to the axis may be incident upon a lens striking either one or the other of its two surfaces. In both cases, one particular ray will always be found which coincides with the axis and which will be transmitted through the lens without suffering refraction.



Real principal foci in convergent lens.

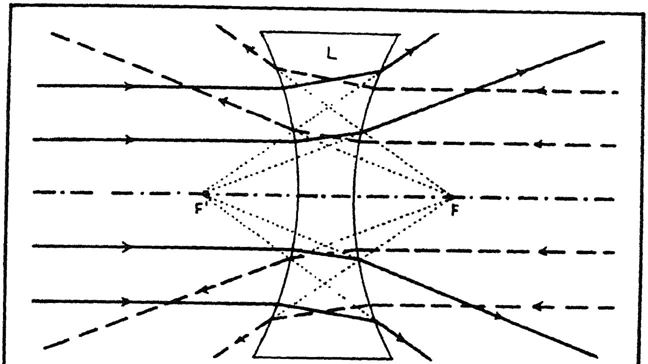
All other paraxial rays parallel to this principal ray and traveling from left to right (traced as full lines in the figure) will be so refracted by the lens that they will meet at a point *f′* of the axis which is called the *second principal focal point* of the lens and which lies behind the lens itself.

Vice versa, paraxial rays parallel to the axis proceeding in a direction from right to left (traced as broken lines in the figure) will, after refraction, meet at a point on the axis in front of the lens and form the real first principal focal point of the lens which is designated by the letter *f*.

Although the lens chosen in the figure for the demonstration of the formation of the focal points is a *biconvex* it is quite evident that a similar construction will determine the foci of plano-convex lenses and convergent menisci.

Concave or divergent lenses, as divergent mirrors, do not form real foci and these points are virtually located at the meeting of the prolongation of the refracted rays.

As in the case of convergent lenses the principal foci of divergent lenses are formed by the refraction of the paraxial rays parallel to the axis.



Virtual principal foci in a divergent lens

In the figure the light rays traveling from left to right have been traced as continuous full lines, the rays traveling from right to left have been traced as broken lines while the prolongations of the refracted rays have been traced at dotted lines.

From the figure it is easily deduced that the virtual second focal point in the case of divergent lenses is located in front of the lens at f' and the virtual first focal point of the lens is to be found behind the lens at f.

It is quite evident that the conjugate foci of paraxial object-points situated either on or outside the axis and at a finite distance from the lens may be found by similar constructions as the ones used for the locating of the principal foci.

The formation of the principal foci by a lens, be it convergent or divergent, is the resultant of the characteristics of the lens called the index of refraction and of the curvatures of its faces. This effect can be expressed as the particular power of the lens to impart to the incident rays a certain amount of convergence or divergence.

It has been explained that the propagation of light takes place in the form of spherical waves. Spherical waves proceeding from an infinite distance have a radius of such length that the wave front reaching the lens may be considered a plane. As soon as such plane wave-front reaches the first surface of a lens each point of this surface becomes a center of disturbance and the refracted rays in their new path of propagation form a wave-front which has a curvature dependent upon the power of the lens. This power will be *positive* for convergent lenses and *negative* for divergent ones and thereby convergent lenses are called positive and designated by the sign plus (+) while divergent lenses are called negative and are designated by the sign minus (—).

IMAGE FORMATION BY PLANE MIRRORS

A mirror is a surface possessing a high reflecting power. The rays of light emitted from an object placed in front of a mirror are reflected by its surface, following the laws of reflection, and the eye placed in front of the mirror in any position will receive these rays which, reflected by the surface, will enter its pupil.

The eye will then see an image of the object as if the rays were coming from behind the mirror.

The part of the science of optics which deals with the phenomena of reflection and especially with the formation of images by mirrors is called *catoptrics*, and an instrument which forms images by reflection is called a *catoptric instrument.*

It is evident that the image of any and all points of the object is seen in the direction of the imaginary prolongation of the reflected rays at a distance equal to that of the given points so that it will appear of equal size as the object it will be erect, but reversed as to sides.

Such an image has no real existence. The rays do not come from behind the mirror and cannot therefore be collected upon a screen. The real image which provokes the visual stimulus in the brain is formed by the optical system of the eye, the position of the image formed by the mirror being only an impression having no real existence. Such an image is called *virtual.* Any virtual image can be made to form a *real* one by a suitable refraction through a convergent optical system as in the case of the eye above referred to.

It is quite appropriate to make here a distinction between the true meaning of the word mirror and the same word as applied to describe the well known object of everyday use.

A mirror, in optics, is a smooth and highly polished surface reflecting a great amount of the rays of light impinging upon it. A glass mirror is in fact composed of a mirror and a support, the mirror being the silver or mercury surface and the glass acting as support and protection to the mirror itself.

A glass mirror has two reflecting surfaces, the front face of the glass plate and the silver or mercury coating on the opposite face.

If a lighted match is placed in front of a glass mirror and is looked at obliquely, two very distinct images of the match will be seen. One of the two images is formed by reflection from the silver coating and is the brightest of the two, the other is formed by the reflection of the surface of the glass.

Furthermore these two images act as luminous objects in respect to either one of the two reflecting surfaces and other images of the match are to be seen which would multiply to an infinite number were it not for the absorption and scattering of the certain portion of the light which takes place at each reflection.

THIRD DIMENSION PERSPECTIVE

Stereoscopic perspective was first postulated by Helmholtz, away back in 1821-94. His theory was widely attacked and ridiculed even though he had made many highly important contributions to the science of stereoscopy.

One of those who did agree with Helmholtz was T. Nakken who has had a varied career in the electro-optico-mechanical field, and is one of the developers of the photoelectric cell now used in motion pictures. The following is an exerpt from an article prepared by Nakken.

The invention of the stereoscope in 1832 seemed to hold great promise. Here two pictures of the same subject are produced by means of two cameras spaced 6.5 cm apart, a distance equal to the average inter-pupillary seperation of the eyes. These pictures, of course, are slightly different in the same way that the two images on the retinas of the eyes are slightly different from each other.

Just as a single picture viewed monocularly can be an adequate substitute for reality, so do these two pictures substitute for that which the two eyes would see in a given scene, provided of course, that the left and right eyes view only left and right pictures respectively. When these two pictures are viewed under proper conditions, the effect is one of startling realism.

Why should this be so?

In normal vision scenes are imaged by the eyelenses on the two retinas, the sensitive elements of which are individually connected, by means of the nerve strands, to the visual perception center of the brain, often called the cortinal retina. Should these interconnecting nerve strands become severed or diseased, partial or even total blindness results, even if both eyes appear completely normal.

In the cortical retina the two images merge and are impinged on the consciousness as a single image instead of two separate and distinct images. This ability of the cortical retina or brain appears miraculous when contrasted with the results obtained when other means are employed to attain the same end—a jumbled, confusing double picture.

In the stereoscope two pictures are presented to the eyes under almost identical circumstances, as when Nature is normally observed binocularly. Obviously, the same process of merging two images with identical spatial sensations occurs in the cortical retina.

It has been established definitely that the eye possesses only a single spot in the retina where sharp focusing is possible, the fovea lutea, which serves as a scanning device to so sweep a scene as to cause individual sharp imaging of detail.

Immediately outside the fovea there is no sharpness of the retinal image.

Clearly, then, when viewing a scene one sees only a single detail with great acuity, the surroundings becoming progressively more hazy with distance from that detail. In fact, by simply concentrating on one object in a scene, everything surrounding that object becomes hazy in outline to the point of non-recognition. The fact that we seem to see the entire scene sharply is due to the very rapid scanning motion of the eye which brings successive details into sharp focus.

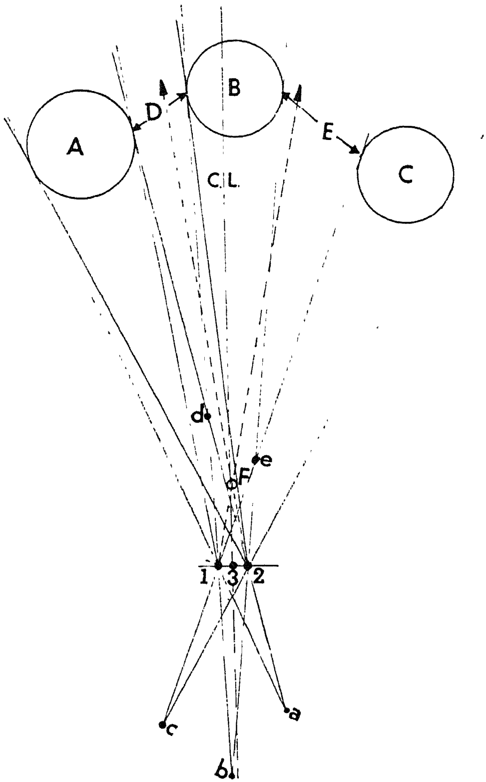
When a scene is viewed binocularly, the foveas of both eyes scan the same details simultaneously. The areas immediately surrounding these details are naturally hazy in both eyes, the merging of these hazily-seen surroundings resulting in a new impression with a "mixed" perspective, the confusion and haziness of which, however, is not much greater than in each retinal image separately.

It seems clear, therefore, that while details are seen sharply and as well-defined entities, they are surrounded by a vaguely-perceived background which is a mixture of the perspectives seen by the eyes separately. This hazy, mixed perspective, and the doubling effects occurring farther away from the sharp foveal impressions, are experienced as the stereoscopic perspective. The sharply observed cortical image, composed of details viewed binocularly, is assembled in an amazingly fast manner.

It is the writer's opinion that the binocular sensation of depth, solidity and space results from the fact that the sharply-seen cortical image is not a merger of two dissimilar images but is rather an image built up in the manner described from details, each one of which was seen in merged, stereoscopic surroundings.

The passing years witnessing no advance in the understanding of the nature of stereoscopic vision as such, there developed the conviction in the minds of workers in the art that three-dimensional vision could be attained only by the merger in the brain of two separate parallaxially-different images. They ignored the simple fact that one-eyed drivers apparently are as good judges of space and distance as are two-eyed drivers, and that there are first-rate tennis players and other athletes who hit the ball consistently, despite the lack of stereo vision.

Many years ago the writer coined the term "trimensional perspective," which will be encountered several times herein, and the characteristics of which may be recognized and derived by diligent consideration of the diagram.



This diagram differs from those used in optical texts in which, generally, two colossal eyes are shown looking cross-eyed at a very small object at a distance about equal to or somewhat less than the interpupillary distance of the eyes.

In the diagram two eyes, 1 and 2 represented by dots are placed rather close together and look at objects A, B and C in a scene placed at an appreciable distance from the eyes. The figure represents a top view of eyes and scene; the objects, shown as circles, might be three round tables or have any other conceivable shape.

When both eyes look toward object A, it is clear that left eye 1 will see more of this object on the left side, and, conversely, that right eye 2 will see more of this object on the right side. This is apparent from the lines of vision drawn through the two eyes tangent to object A. Obviously, the two extreme lines of vision embrace more of the object than the lines of vision of either one of the two eyes. When now we extend these two extreme lines of vision, we find that they cross each other at point a located behind the eye base and on the side of the centerline opposite to that in which the object is located.

Now, if a single eye were placed at this crossover point a, it would view object A while embracing as much of its girth as do the two eyes 1 and 2. Thus point a may be designated the equivalent viewing point for eyes 1 and 2 with respect to object A, because from there a single eye sees the object along the extreme. lines of vision of the two eyes.

The extreme lines of vision for the two eyes viewing object B reveal the existence of another equivalent viewing point, b; and similarly we find an equivalent viewing point c for object C.

Looking at the lines of vision from these equivalent viewpoints, and at the lines of vision from either one of the eyes, we find that in each case the object obtends an angle which is smaller, in the case of the equivalent viewpoints, than in the case of either eye viewing a particular object. Hence, as the angle obtended by an object is the sole factor which determines its linear dimension in an image, it is clear that all objects are seen narrower in binocular than in monocular viewing.

The word "narrower" is used advisedly because vertically both eyes are on the same level and thus see the vertical characteristics of an object (and space) under identical angles. Therefore, as far as vertical phenomena are concerned, we might just as well have a single eye at point 3.

Pausing here a moment, we might consider that in a single stroke we have unraveled part of the enigma of binocular vision. We find that in the perspective created binocularly there is but a single vertical center of vision or perspective; while there is a plurality of horizontal centers of vision, these being the equivalent viewing points for the two eyes for each and every object in a scene.

We find, further, that in the binocular perspective objects are imaged narrower than in the geometric perspective, because horizontally these objects obtend smaller angles than those obtended in the monocular, geometric perspective. We know also that objects to the right of center in a scene are seen, in the binocular perspective, from the left of center; while objects in the left of the scene are viewed from the right.

However, the difference in angles obtended in the two different kinds of perspective may become so small as to be insignificant. This happens when this difference becomes less than the angle of the retinal curve obtended by a single visual element, because then no difference in dimension can be observed anymore, according to the teachings of conventional stereoscopists. This occurs when light rays from the objects reach the eyes substantially as parallel rays, which happens with increase in distance of the objects.

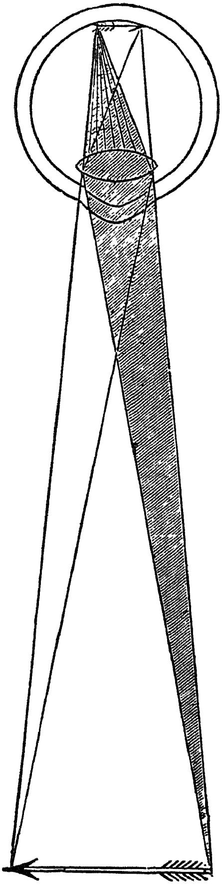


Diagram showing how Objects are imprinted on the Retina.

Thus at the "critical stereoscopic distance" this difference in angle obtended disappears, and the binocular perspective merges into the geometric perspective. The narrowing down, or slenderinzing, of the images of objects is strongest for nearby objects, decreases gradually with distance, at last to become zero.

Returning to the diagram, we now will consider another, and extremely interesting, fact. Between objects A and B there is a space, designated by D; and between objects B and C there is a space, E. Close inspection reveals that the two eyes, looking through these interspaces at the background, again do so binocularly and show, once more, extreme lines of vision.

For space D these extreme lines of vision are the line drawn from left eye 1 tangent to the left side of object B, and the line drawn from right eye 2 tangent to the right side of object A. These two extreme lines of vision cross each other at point d, which, therefore, is the point from which a single eye would look through the interspace between objects A and B, in the same manner as do the two eyes 1 and 2.

Point d, therefore, may be designated as the equivalent point of vision for the eyes 1 and 2, as regards interspace D. For space E we find, in an exactly similar manner, an equivalent viewpoint e, from which a single eye would see this space in the same manner as do the two eyes 1 and 2.

In the case of these equivalent viewpoints for interspace we find, however, that they are located in front of the eye baseline. Moreover, we see that the angles obtended by the interspace from these points are larger than those from either one of the two eyes. This means of course, that the interspaces are seen in widened proportions, in contradistinction to the slenderizing effect we found to occur with objects. Again, the term "widen ing of the interspaces" is used advisedly, because, vertically, there still is no change in proportions, as vertically the eyes are on the same level.

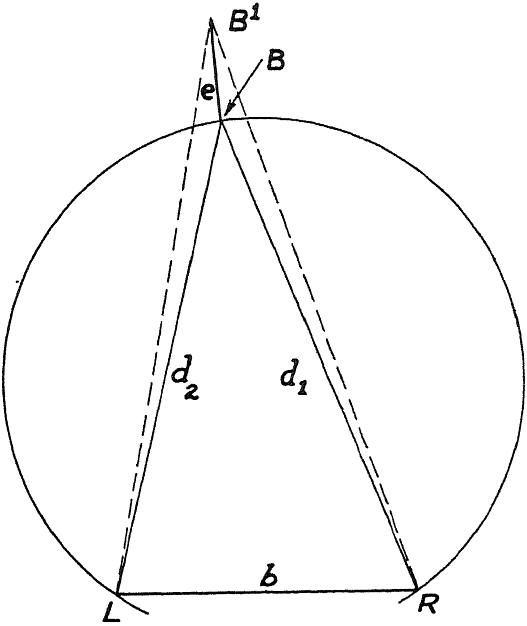
Expressed simply, we find that in binocular vision we look through the interspaces between objects from a multitude of points located in front of the eye base, and under wider angles, so that, binocularly, we are enabled to see more of the background than is possible with either eye.

Again, this increase of angle with which in binocular vision we look through interspaces, decreases with distance until, beyond the critical distance discussed previously, the difference in angles obtended by spaces becomes equivalent to zero. Hence this cause for stereo vision also ceases to exist at the critical distance.

We are now in a position to define clearly the difference between the perspective seen in binocular vision and the geometric, or monocular, perspective.

In the latter, there is but a single viewing center or center of perspective, i.e., the center of the eyeball, or the objective of a camera; while the former possesses three different kinds of viewpoints: first, a single center of perspective in the vertical sense, which may be said to be located at a point midway between the two eyes; second, a group of viewpoints for objects, located behind the eye baseline on the opposite side of the centerline to that on which the objects are located; third, a group of viewpoints located in front of this baseline from which interspaces are viewed, on the same side of the center line as these interspaces themselves.

It follows that as a result of the widely different locations of these various viewing points, the binocular perspective is totally different from the monocular, geometric perspective. As was shown, objects are slenderized, by a given percentage, which is greatest for nearby objects and decreases with distance. Conversely, interspaces are widened, by a given percentage, which again is greatest for spaces between nearby objects and again decreases with distance. Beyond the critical stereoscopic distance, however, both objects and interspaces are seen with the geometric perspective.



Illustrating parallax and the differential parallax.

Expressing these facts differently: it is often that when looking at Nature or in the stereoscope, we "look around" objects in the foreground. Of course, as the distance of these objects increases, this "looking around" effect decreases and gradually disappears, to become zero at the *critical distance*.

Now, if one looks around an object in the foreground, one must see more of the background: The diagram shows that this is exactly what happens, due to the slenderizing of foreground objects and the location of the interspace viewing points, from which "more" of the background is visible than from the location of either one of the eyes.

Between the extreme narrowing down of objects and widening of interspaces and the geometric, monocular aspect beyond the critical distance, there exist, of course, *an infinite number of gradations.* In practical terms this means that, for instance, when a person is seen at a distance of 10 feet he appears more slender than when seen at 20 feet, and that at 20 feet he appears to be more slender than when seen at 50 feet distant; while after the *critical* distance is reached, the person is seen in the proportions which, in the geometric perspective, obtain at any and all distances.

It is quite evident, of course, that the facts here enumerated lend themselves to exact mathematical analysis. Taking the interpupillary distance at an average of 6.5 cm, the percentage of slendering effect may be calculated for any chosen distance, as may be the opening up of the interspacings in the binocular image.

There is one special case to be considered in connection with the stereoscopic perspective, relating to what happens when very narrow objects are seen at an extremely short distance. Such an object is shown at F. Obviously, in order to view this object sharply binocularly, the eyes must assume a crosseyed position. When they do this, the background becomes at once jumbled and doubled up. If, however, one focuses the eyes on an object in the background, the object is projected into the background twice.

These facts anent the double-imaging of objects in stereoscopic or binocular vision are highly important in terms of applying the stereoscopic perspectve to photography, in which case the double image would be disastrous.

The perspective which has all the characteristics of the stereoscopic perspective, with the exception of the aforementioned double image, is that for which the writer has devised the name "trimensional perspective."

The writer feels that in deriving the properties and characteristics of the stereoscopic perspective, no less than in reducing it to definite terms, he has proven conclusively that Helmholtz was completely right when he postulated its existence. Had Helmholtz lived to see motion pictures, and particularly a film produced by a transversely moving camera, his belief in the existence of the stereoscopic perspective would have become a certainty.

The bald fact is that the advent of the sterescope, while a brilliant invention, served only to confuse investigators and thus barred the road to further progress and a true insight into the stereoscopic perspective. It gave rise to the universally accepted table that there existed in the brain an enigma which could not be solved with the means available to science, and which might very well be beyond the powers of the human mind to comprehend.

The solution to this enigma was hidden in the mysterious convolutions of the *cortica,* which alone possessed the power to merge two visual images. This cortical-merged image, which defied measurement and thus any systematic analysis, is held by the writer to have been proven herein to be completely accessible to the mind and subject to precise definition.

Once scientific workers possess the facts relating to binocular or stereoscopic vision (namely the creation of a specific, definable and calculable perspective which obeys laws as rigid as those governing the geometric perspective), it becomes a simple matter to produce optical aggregates which will produce single images with all the attributes of stereoscopic vision. In fact, the writer many years ago constructed such apparatus, which gave promise of achieving the desired results.

Whenever such an aggregate was handed to an optical calculator, the desired effects promptly disappeared. The aggregate become capable of producing the undistorted, geometric perspective, because the calculator knew that only this "perfect" perspective must be the aim of his work.

In the motion picture field, several attempts have been made to produce stereoscopic effects by means of distortions applied to the individual pictures, either during the taking or in the projection process. Considering the data contained in this chapter, it is obvious that no amount of distortion in a geometrically correct picture will ever produce the stereoscopic perspective.

Several attempts have been made to project rea images standing in the air in front of concave mirror arrangements, notably by Dr. Kogel in Germany, who used a mosaic of concave mirrors with quite some success

It is pertinent to mention the attempts to create stereo effects by means of projecting alternating stereo pairs. High hopes were held by this process because o the striking stero effects experienced when viewing a film made by a transversely-moving camera. Helmholtz would have immediately recognized the true significance of this phenomena.

Such films serve to discredit the erroneous concept that *spatial vision* may be attained only if each eye sees only its proper image, and that two paraxially different images must be seen separately by two eyes in order to be merged in the brain.

These films consist of a series of pictures each one of which, together with the previous or the following one, forms a stereo pair. When projected, these images are seen in succession. Often the effect is startlingly real and truly stereoscopic, as one observes depth and solidity and looks at space rather than a flat screen. Yet, this succession of stereo pictures, as such films really are, is always seen simultaneously with both eyes (or by one-eyed people with a single eye) so that the mysterious merging power of the brain seems to work for images in succession just as well as for separate stereo images seen with different eyes.

The reason for this merging process in time lies, of course, in persistence of vision whereby we see the image which just left the screen and the one being projected. As both foveas are always directed at the same center of momentary interest, complete merging of the parts of the picture adjacent to such centers of interest becomes quite easy, again because these are seen only with great haziness anyway, so that no greater confusion need be felt if two separate pictures are mixed around the center of interest.

If, now, alternate pictures taken from the right and left are projected, the stereo sensation arises in the same manner but is accompanied by a rapidly rising feeling of fatigue, because the eyes are compelled to center the two foveas on an oscillating center of interest.

This represents a definite hardship, of course, and moreover creates the impression of excessive flicker.

Photographic aggregates, as stated previously, can be made which produce single images with all the attributes of stereoscopic vision and which the writer termed "trimensional images." Pictures made with such an aggregate, whether seen with both eyes or a single eye, convey an impression of depth, solidity and space.

Pictures made with trimensional aggregates may be printed on ordinary paper or projected with conventional projection apparatus. No special films, screens, analyzers nor any special viewing devices or separators are required for viewing whether by one-eye or two-eyed people.

Repeatedly the opinion has been voiced that if we possessed four eyes positioned, for instance, in a diamond shape, we would be able to see stereoscopically "all around" and the result would be a more acute perception of depth. This period is important, because the optical trade would be able to make aggregates with this "quadrocular" perspective just as easily and certainly with greater accuracy than they could make aggregates with the binocular perspective.

We know it to be a fact that if we hold our head sideways, we perceive stereoscopy in the *vertical* sense. Nature ignored the opportunity to endow us with this, possibly superior, stereo vision, thus we must live our lives out as binocular bipeds. It is doubtful whether the easily attained quadrocular perspective would be any real improvement.

The perception of depth, solidity and space, the writer opines, is an *acquired, experienced* faculty. One-eyed people develop this faculty in a different manner, but it remains an *acquired* faculty. We are a binocular people, by a wide majority, and that's that.

Analysis of the perspective we perceive shows that horizontally we see objects narrowed down and interspaces widened. Further, we noted that ratios of width to height change with distance, and this change is part of the fund of experience utilized in our acquired perceptions of depth and distance. The writer feels that this measuring rod, subconsciously applied, must be an important part of our mental visual armamentum.

This interpretation of changing ratios between width and height, however, would be totally lacking in the quadrocular perspective, as can be easily proven by an analysis similar to that applied to the binocular or trimensional perspective.

At best, it's a moot question just what kind of perspective should be adopted for photographic purposes, with the final judgment doubtless reposing with the general public after having viewed one or the other kind of perspective.

Trimensional pictures, the writer is certain, will replace the present geometric pictures as a matter of course. The trimensional perspective will lend a touch of amazing relaity to photographs and reproductions of any and all kinds whatsoever. The effects will be retained in the halftone process, will be universally used in illustrated magazines, and add immeasurably to the enjoyment of all pictorial work.

In motion pictures the trimensional perspective will add the final needed touch of reality, particularly if a good color process is employed in making the films. As this perspective depends only on the optical characteristics of the aggregate used as a camera objective, there would be no difference in treatment as between black-and-white and colored film.

WIDE FILM

The present trend in the industry is for a change in the "aspect ratio," the relationship of picture height to width, however, this is by no means anything new, we have had proposals for such a change many times over the past years.

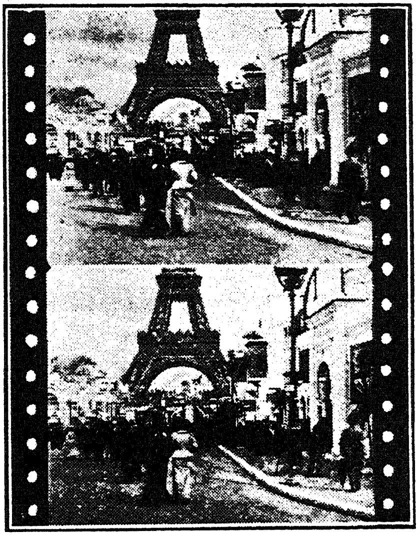
It has long been known, that the human eyes take in a much wider view, horizontally, than they do vertically. The average range of human vision is 165 degrees horizontally and but 60 degrees vertically. It would therefore appear that a more pleasing picture would be one that approximates this ratio, rather than the 3 to 4 ratio now in standard use.

The standard ratio of 3 to 4 was that first used by Edison in this country and by Lumiere in France, at the birth of the motion picture, however, within the life span of the industry many larger ratios and film widths have been used and proposed. In 1899, there were at least a dozen motion picture cameras and projectors on the market that used a film wider than the present standard, the English Prestwitch machines used a film 2⅜ inches wide. The films used in the Mutograph in this same year were 2¾ inches wide. A motion picture made by William Friese-Greene in Brighton, England, in 1899 used a paper film with frames 2½ inches wide and 1½ inches high.

The Latham Eidoloscope, built in this country, used a film two inches wide, each frame being 1½ inches long by ¾ of an inch high. A film used to photograph the Jeffries-Sharkey prize fight, held in

Coney Island, New York, on November 3rd, 1899 was 2¾ inches wide, and each frame was 2¼ inches high.

All of these odd sized films together with the equipment in which they were used, passed out of the industry early in the new century, the Edision and Lumiere standard being then adopted.

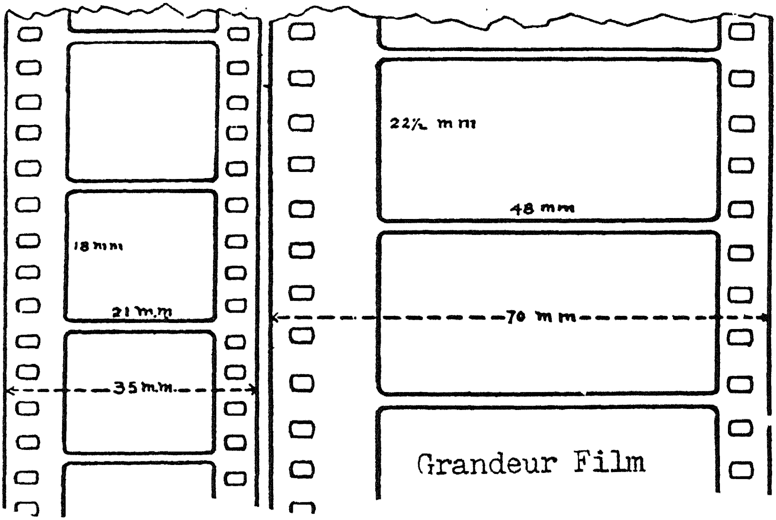


Print from film taken on opening day of Paris Exposition of 1900 in Lumière camera using wide film (4.5 X 6 cm. frame).

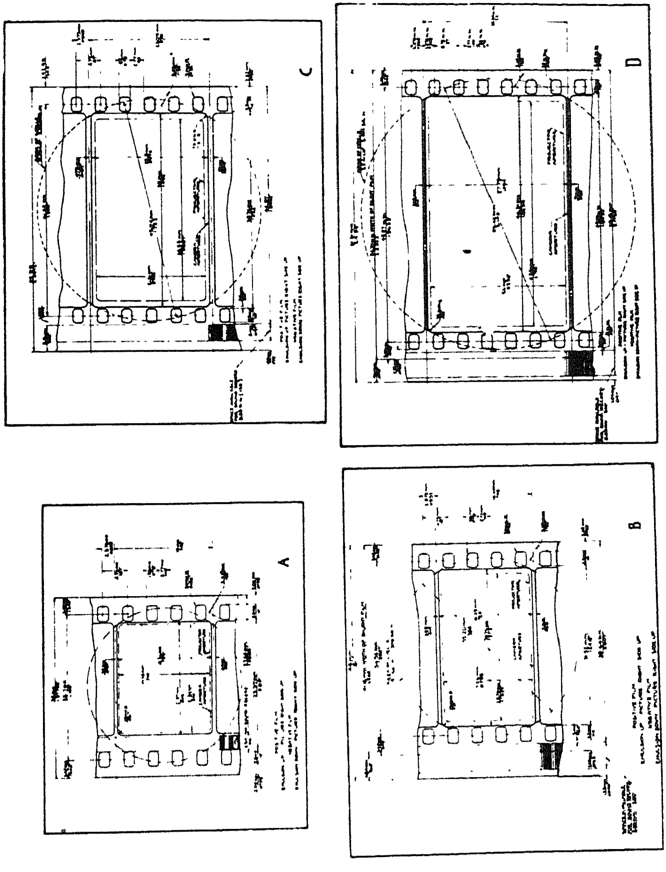
With the advent of sound-on-film, part of the film had to be given over to the sound track, thus cutting down the space used for the photographic action, and this in turn again altered the "aspect ratio" of the screen picture.

This again brought up the question of a wider screen picture, and the industry was again confronted with the question of just how much wider the film should be. Paramount experimented with a film 56 mm in width, RCA with a film 63.5 mm in width, Bell and Howell proposed other standards, as did Widescope.

Spoor a name long associated in the industry (the S in Spoor with the A in Anderson made up the old producing concern of Essanay in Chicago, who produced the early cowboy picture series of Bronco Billy about 1910) introduced a film 63 mm in width, which they called Natural Vision Pictures.

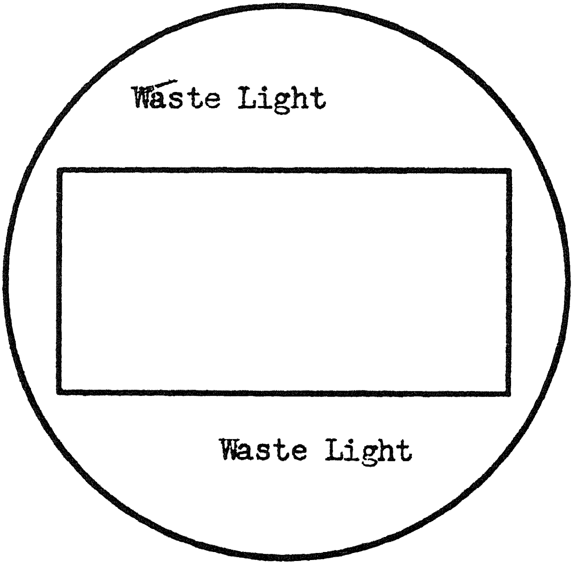


Fox released a picture made on film 70 mm wide under the name of Grandeur Pictures, these reached the screen at the Gaiety Theater on Broadway, New York, late in 1929. The program consisted of a picture of Niagara Falls, a Fox Newsreel (on 70 mm) and the feature FOX MOVIETONE FOLLIES of 1929.



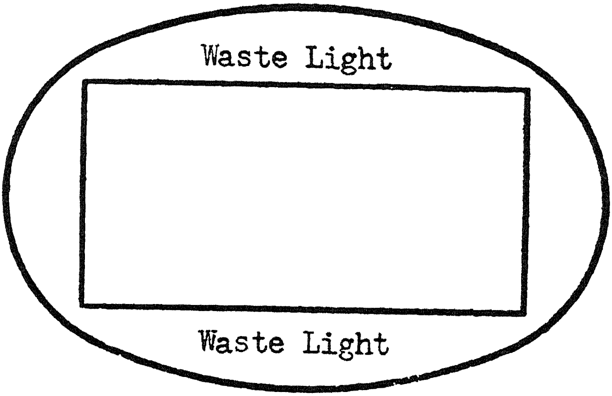
Proposed dimensions of wide films compared with the 35 mm. standard. (A) 35 mm. film. (B) "Economic." (C) "Spectacular." (D) "Extreme."

The picture frame was $22\frac{1}{4}$ mm by 48 mm, which left a sound track space of 7 mm wide, the film was made by Eastman, and being twice the width of standard film, cost just twice as much per foot. The camera used in making the pictures was built by Mitchell Camera Corp., the gears in the camera were differently cut, due to the change in pitch of the film perforations, and the camera shutter had, of course, to be greatly enlarged, the camera was fitted with special lenses, which were designed by the Bausch & Lomb Company, who also made the special optical system used in projecting the picture.



The Grandeur Projector was built by International Projector Corp., this was a hand built model, it weighed over 1,600 lbs. The film came on 2,000 foot reels each reel weighed 35 lbs.

The light source was a high intensity arc operating at 150 amperes. The pictures were projected onto a screen 35 feet wide and 17½ feet high, this was the limit in size due to the size of the proscenium arch at the Gaiety Theater. The length of throw was 70 feet. In using any film with a width of approximately twice the size of the height, a special condensing system is necessary, if a serious loss of light at the gate aperture is to be avoided. With an ordinary condenser combination throwing a round spot on the aperture as shown in the diagram, the loss of light would, as can be seen, a very serious matter, this loss could be materially reduced by employing a condenser system capable of throwing an elliptical spot of light, as shown in the illustration.



This special condensing system was designed by Bausch and Lomb Company of Rochester, N. Y.

The use of wide film, at least a film wider than the present standard 35 mm, has a lot to recommend it, the cameraman has a much greater scope in his composition, and considerable advantages in his lighting, especially as regards top-lighting and back-lighting. Direction of expansive scenes is greatly simplified. Sets do not have to be built so high. Scenes do not have to be "followed" with the camera, as there is ample room in a normal "long-shot" for all lateral movement, used in most sequences. It offers advantages to the recording of sound as the recorder would have a much wider sound-track to work with. It was generally agreed by all those who witnessed the showing of the picture on opening night, that the picture was much more pleasing to the eye.

One of the men responsible for the development of Grandeur pictures was A. E. Sponable, who together with Case developed Fox Movietone sound, and who is today now working on the new Fox expanded screen picture to be known as CinemaScope.

You might ask, well what happened to the new trend towards wide screen pictures. The new equipment and the change-over in the studios, was to cost real money, and before the powers-that-be could decide if the investment would prove worth while, the stock market crashed and the country was faced with years of depression.

This chapter has up 'til now dealt with the wide screen picture, obtained by increasing the width of the motion picture film and the width of the gate aperture in the projector. The new expanded screen picture used by Cinerama is obtained by the use of three projectors, each projector filling one-third of the width of the screen picture. The new Fox CinemaScope expanded screen picture is obtained by the use of a special compression lens in making the picture and then employing an expansion lens on the projectors when showing the pictures. The film in both systems being the standard 35 mm.

The introduction of wide film pictures present many optical problems, for the producer, the exhibitor, and the manufacturer of motion picture equipment, these problems were well covered in a paper prepared by W. B. Rayton, of Bausch and Lomb Optical Company, back in 1930.

The employment of film wider than the standard 35 mm. seems imminent. No one can say whether we will have to deal with one size or several, but, however that question may be settled, the difficulties encountered in designing adequate optical systems are of the same kind in all cases but differ in degree with the variations in width of film and size of projected image. It seems probable that they are of sufficient interest to justify a brief statement of them and of the degree to which we have been able to meet the requirements.

It will probably not be out of place first to set forth the reasons which are impelling the industry to take a step involving such drastic changes in equipment while it is still struggling with conversion of equipment to permit sound pictures to be made and reproduced. While there may be other reasons, there are two, at least, discoverable by a brief consideration of sound pictures. The first rests on the fact that in the sound-on-film processes part of the area formerly available for the picture now has to be given up for the sound track. The second reason rests on the possibilities inherent in sound pictures which were lacking in the silent pictures of presenting entertainment more of the nature of spoken drama of the stage. Although the second of these conditions leads to a demand for a larger picture area, the first results in an actual decrease in picture area.

As soon as speech was added to the picture it was found that the picture area did not allow enough characters to be included in a scene if the projected images were to appear large enough to be commensurate with a sufficient volume of sound. The effect of a series of conversations between two or three characters appearing in a small, practically square frame in the remote distance is distinctly not entertaining after the novelty has worn off. Further, the producers are ambitious to attempt to record the stage settings as well as the music of opera and musical comedies.

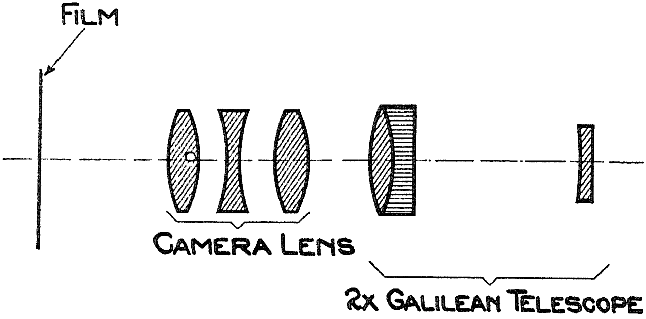
To meet the situation it is necessary to project a picture in which the figures remain of a sufficiently large size but which includes more of them. This means, obviously, a wider included angular field of view and a larger projected picture.

To accomplish this, two methods of attack occur at once. One method would consist in moving the camera farther from the set or in using lenses of shorter focal length thereby reducing the size of the images of the individual components of the set and permitting more of them to be included. Now, if this picture is projected through a projection lens of sufficient power to restore the figures to the customary size on the screen, a much larger total picture size will result. It will be larger in height as well as in width. Since we are only infrequently interested in any great amount of space above the heads of the human figures in the set we would be embarrassed with this superfluous space, in general. It would be possible, however, to reduce the frame height, let us say, to the point where its relation to the height of the human figures was restored to somthing like what we have been accustomed to. Now this all sounds very good. Several more frames, possibly twice as many, could be recorded on a foot of film;

film consumption would be decreased and film magazines reduced in size or else hold a much longer record.

This procedure, however, is impractical, first because the resolving power of photographic emulsions of adequate speed is insufficient to permit a satisfactory screen image to be obtained by such a process. Graininess would be very pronounced and detail would be lost. It would, furthermore, be impractical in the present state of development of the optical systems employed in the sound-on-film processes since it would be impossible to get a satisfactory reproduction of sound because of the loss of high frequencies. Finally, it is not at all sure that such a picture could be projected with anything like a satisfactory degree of brightness.

A modification of this solution was demonstrated at the meeting of the Optical Society of America at its meeting in Washington in November, 1928, which is interesting enough to justify examination. You have probably all observed that if you had a telescope of any kind before your eye in a reversed position all objects seen through it are apparently reduced in size and look more remote. If you hold a telescope before the lens of your camera you will be able to observe the same effect on the ground glass. If the telescope be held before the camera lens in its ordinary operative condition the image on the ground glass will be larger than the image formed by the camera objective alone. To be more specific, if we hold a 2X Galilean telescope in front of the camera lens with the objective lens of the telescope facing the camera as shown in the diagram the size of all the individual details in the image on the ground glass will be just half as large as they are without the telescope. If you try this experiment do not be surprised, however, if the total image fails to cover the whole ground glass area; the ordinary Galilean telescope optics serve only to demonstrate the principle but will not give results of any value. Provided, however, the optical system was satisfactory we would have achieved a result identical with the result we might have obtained with a new camera objective of just half the focal length of the original. You will remember that this is one of the expedients mentioned a moment ago for increasing the angular field of view. The proposal under examination, however, is unique in that instead of lenses with spherical surfaces it employs lenses with cylindrical surfaces so that the added telescope, if we may still call it such, has magnifying power in one direction only, while in the direction at right angles it has no optical effect at all. If such a system be added to a camera lens it will have the effect of apparently altering the focal length of the latter in one diameter while having no effect on focal length in a second diameter perpendicular to the first. If the added system be located such that its active plane is horizontal we would be in effect taking a picture through a lens of,



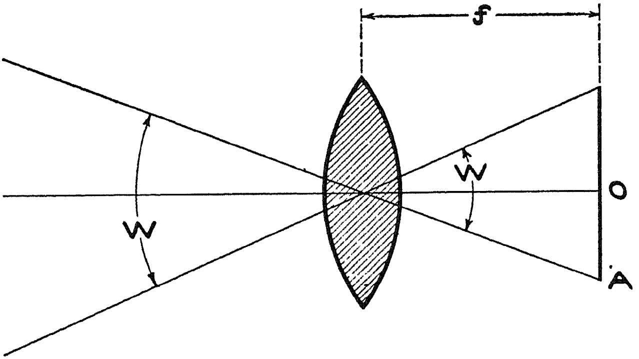
A photographic lens to which a 2X Galilean telescope is added to reduce the focal length to half of its original value.

let us say, two inches in the vertical plane and one inch in the horizontal. The result would be that all vertical lines would be brought closer together and more space could be covered in the horizontal plane while the height of the figures would be normal for a 2 in. lens. The image on the film would be a very unusual looking image but projected through a projection lens with a similar added cylindrical system it will be restored to normal proportions and theoretically the projected picture would give no indication that it has been subjected to such unusual treatment.

If an optical system of this type could be designed to work satisfactorily in respect to speed and image quality, a task bristling with difficulties, it would overcome the difficulty mentioned earlier of poor sound reproduction and it would probably be somewhat easier from the illumination standpoint. From the standpoint of image quality, however, even neglecting the effect of aberrations in the added system itself it is not obvious that we would obtain results of any better quality than we would secure by photographing with an ordinary photographic lens of correspondingly short focus and projecting with correspondingly higher magnification.

We would, to be sure, have the great reduction in photography and the extraordinary magnification in projection in the horizontal plane only instead of in all directions, but it does not seem likely that this would reduce in any appreciable degree the difficulties due to grain and limited resolving power of the film.

The successful application of the methods previously outlined imposes problems on both the lens designer and on the emulsion maker. There is one possibility, however, which leaves the film manufacturer free from embarrassment in so far as his emulsions are concerned but which still depends for its success on the lens designer. The method referred to consists in enlarging the picture area without changing the focal length of the lenses. This, translated in optical language, calls for both photographic and projection lenses of larger field of view. For the sake of any who may be unfamiliar with the meaning of the term field of view it may be well to explain that the quotient of half the diagonal of the picture area divided by the focal length of the lens is the tangent of half the angular field of view.



Illustrating the meaning of the expression "angular field of view." AO/*f* equals tangent of one-half of angular field of view.

The commonly used focal lengths in motion picture practice run from 40 mm. to 150 mm. Lenses both shorter and longer are used on occasion but not frequently. The following table presents the values of the angular fields of view demanded by three different picture areas for lenses within these limits.

Beyond doubt the most popular lens in motion picture photography is the 50 mm. lens. On standard film the field of view covered is slightly less than 35°. For the 23 × 46 mm. picture area the field covered is practically $54\frac{1}{2}°$. This is not by any means an unheard-of angle in lenses of relative aperture of *f*/4.5 or even *f*/3.5 but no photographic lens appeared to be available with sufficient speed and satisfactorily sharp definition to cover a picture size 23 × 46 mm. at the same time this size was first attempted. To cover the field with lenses of longer focal length is a task of less difficulty, but here one guard against a deterioration of general definition due to residual aberrations which becomes the more noticeable the longer the focal length.

After the pictures have been taken the problem of projection offers difficulties in illumination and in finding a projection lens competent to project them with satisfactory definition. It is obvious that if the same amount of light which passes through the aperture of the film gate in an ordinary projector, be spread over a screen area twice as large the illumination of the screen image will be only half as great. If a pair of ordinary $4\frac{1}{2}$ inch condensers and high intensity arc be employed in their usual adjustment it will be found impossible to illuminate an area 23 by 46 mm. The illuminated area in the plane of the film is not large enough. The size of the illuminated area can be increased, however, by reducing the distance from the arc to the condenser. An adjustment can be found in which the spot at the film gate will be large enough to circumscribe the 23 by 46 mm. rectangle. It is obvious that much light will be intercepted by the film gate, but still the illumination will be greater than we might expect as a result of comparison of screen image size.

The old $4\frac{1}{2}$-inch diameter condensers with the high intensity arc, however, did not exhaust the possibilities of the projection lens in respect to its angular aperture. One obvious means of increasing illumination, therefore, lay in employing condensers of larger converging angle. Since the approach of the arc to the condenser cannot be carried on indefinitely this led at once to larger condensers. It was possible to obtain a marked increase in angle with condensers of 6 inch diameter with aspheric surfaces, of course. A substantial increase in illumination resulted.

Some additional illumination, however, is possible by using an astigmatic condenser, one whose focal length in one meridian is shorter than its focal length in the other principal meridian. Such a condenser can be realized by employing one cylindrical surface, as we have done for years in aphthalmic instruments, or by employing a toric surface.

A preliminary investigation subject to possible correction indicates a gain of something like 25 per cent obtainable in this manner. If now, the arc be run at something like 150 amperes with condensers as described a satisfactory illumination will be found possible. It still remains a question as to just what degree of illumination will be required. For the projection of these wide pictures, ordinary projection lenses are entirely out of question except in the longest focal lengths because of objectional curvature of field.

COMMERCIAL THIRD DIMENSION and EXPANDED SCREEN SYSTEMS

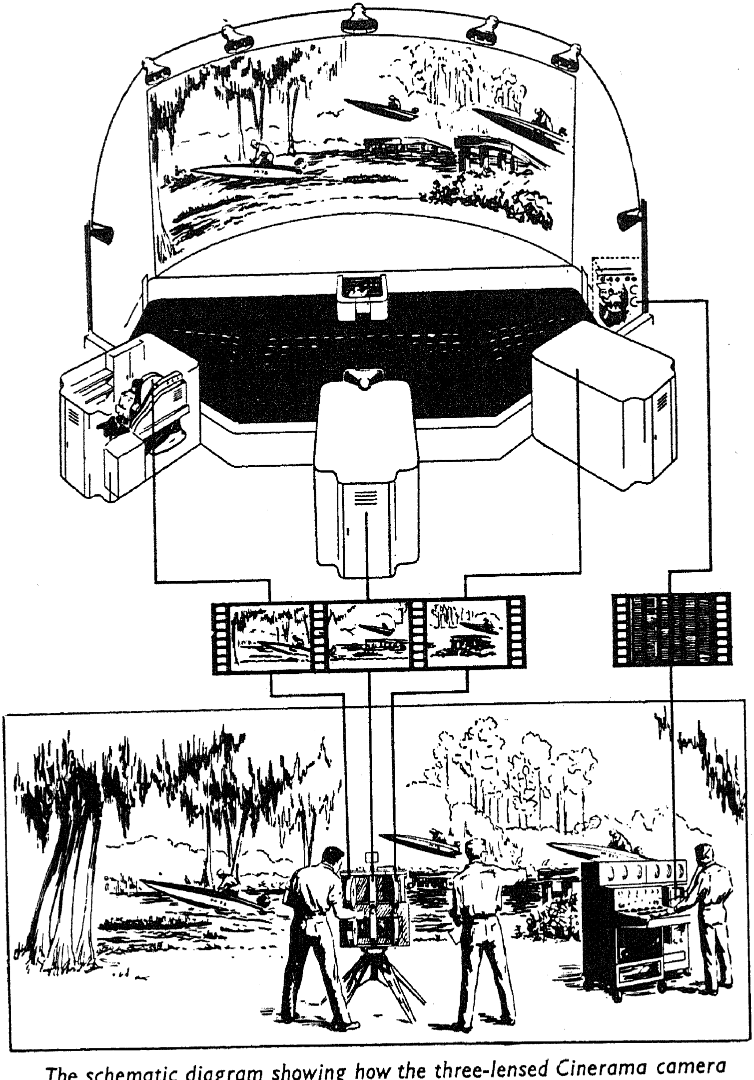
Cinerama

The sponsors of Cinerama do not claim that their pictures are stereoscopic or three dimensional movies, although an illusion of third dimension is certainly created due to the huge size of the screen and its "wrap around" effect.

Fred Waller, late special effects director of Paramount pictures is the inventor of the system, Cinerama being an offshoot of the Waller Flexible Gunnery Trainer which he developed for the U. S. Government during World War II. By using five synchronized projectors on a spherical screen, Waller managed to produce a three dimension picture which closely reproduced the environment of a gunner in combat action and gave him his points of aim to plus or minus two gunnery mills, or better. In addition, it gave the airforce gunner the mental experience of attacking and being attacked and of developing his emotional reactions to the point where he could control them without "buck ague." Wallers Gunnery Trainer is credited with preventing 350,000 casualties in training and combat, these figures being supplied by the U. S. Government.

The principle used in that device is the same as that now employed in Cinerama, with the exception that only three cameras and three projectors are used in Cinerama, as against the five cameras employed in the Gunnery Trainer.

Normal binocular vision, while playing an impor-



The schematic diagram showing how the three-lensed Cinerama camera records the entire scene on three separate strips of film which are subsequently projected, by three synchronised projectors.

tant role in the viewing of motion pictures, is only part of the over-all reason why such images seem real. Cinerama starts from this basis and, by skillfully combining other elements of human vision and intricate compensatory optical and mechanical equipment, produces a stereoscopic effect in the projected screen picture.

The illusion of reality created by the Cinerama process is closely linked to the functions of the retina of the human eye and the drum of the human ear. While a person's attention may be directed primarily at one particular object, his field of vision also encompasses everything on either side of it as far as the corners of the eye can see. Likewise, a man walking down a city street, hears not only the sounds directly in front of him, but also those on either side and behind him as well.

Cinerama seeks to attain these effects of real life by surrounding the viewer completely with action and sound.

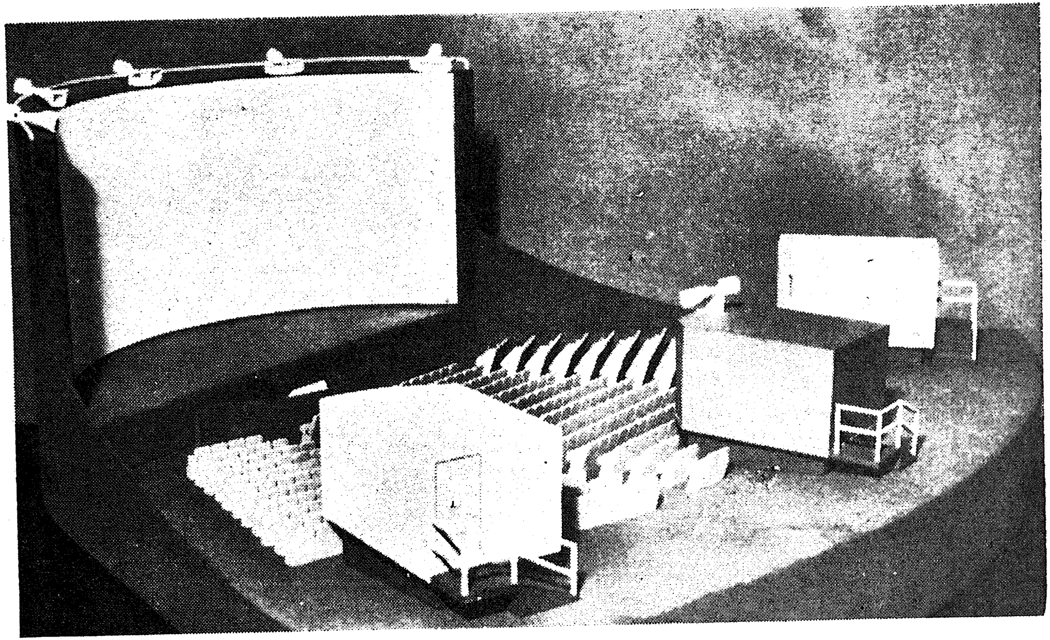
Peripheral vision plays an important part in the total sensation of full dimensional sight. The average range of human vision is 165 degrees horizontally and but 60 degrees vertically. Cinerama closely approximates this visual field by reproducing a screen image 146 degrees by 55 dgrees. This screen proportion not only gives the audience an illusion of stereoscopy but also a sense of actually taking part in the action on the motion picture screen.

Since no single camera could possibly take in a fraction of the visual range of the human eye, the Cinerama camera is actually three cameras in one, it weighs 150 pounds has three matched lenses of 27 mm. focal length which are set at angles 48 degrees apart. The matching of the three lenses is all important. Each lens photographs one-third of the scenes total width on one of the three standard 35 mm. films. The sight lines of the three lenses converge and cross one another at a point 11/16" in front of them; at this point, a single revolving disc shutter is used for all three cameras to assure a perfect synchronization of the exposures. One knob focuses all three lenses at the same time, while another controls the diaphragm apertures. The picture frames used in the camera are half again as high as those of standard height, and since three film strips are used, this means that the total amount of film used is four and one-half times as much as that for a standard 35 mm. motion picture.

The equipment for making Cinerama pictures includes a sound-recording outfit, which uses six omnidirectional microphones to pick up all the sound from every angle that exists in the area being photographed, including the sections on either side and also behind the cameras. The sound is recorded on a magnetic type film recorder which requires no laboratory processing and can be played back immediately to check on the quality of the recording. All of the equipment used in photographing the pictures and recording the sound and also the equipment used in editing the picture had to be specially constructed.

The sound system is new, however, in that the six sound tracks are magnetically recorded and reproduced by the film method developed by the Hazard Reeves organization which now own Cinerama.

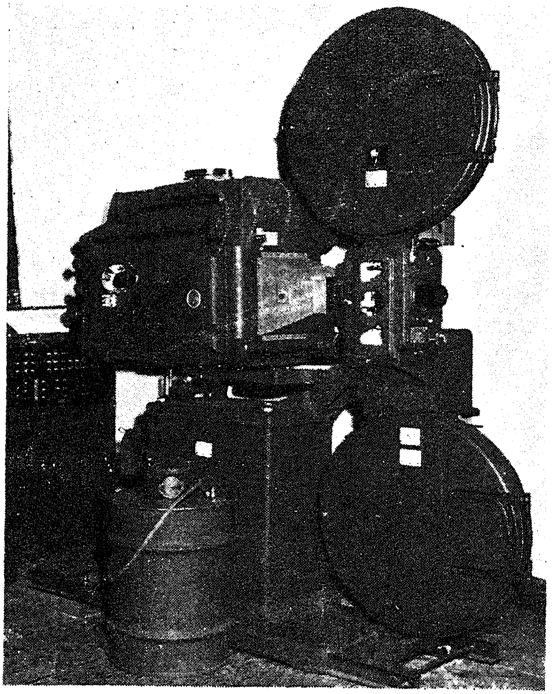
Cinerama uses three projectors installed in three projection rooms. One of the projectors, the one installed on the west side of the theater, shoots the picture onto the East end of the curved screen. The projector installed on the east side of the theater, shoots the picture onto the west end of the curved screen, the third projector installed directly in front center of the curved screen, takes care of the projected picture located di-



SCALE MODEL showing layout of screen and projection booths built for Cinerama at the Broadway Theatre in New York. Horizontal projection is used to help give the best possible picture.

rectly in middle of the screen.

The screen is made up of some 1,100 vertical strips of perforated plastic tape, arranged like the louvers of a venetian blind, this type of screen was necessary due to the fact that when using a "solid" screen light reflec-



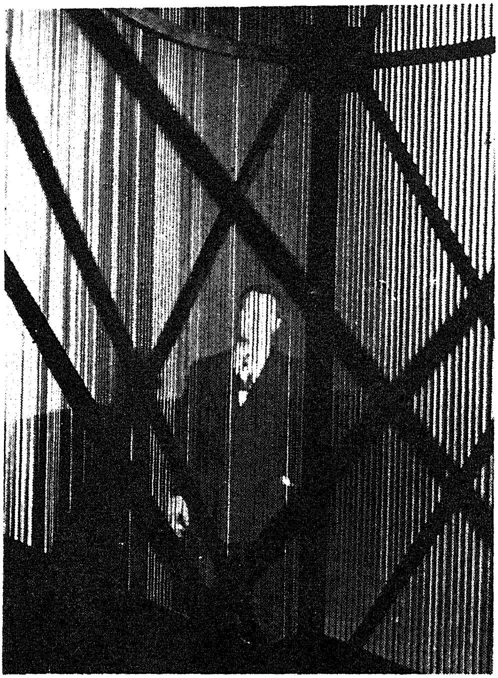
Projection equipment by Century for the Cinerama process. Magazines hold about 8,000 feet of film. The pedestal is of extra-heavy construction and incorporates special micrometer adjustments for alignment of images. Mechanisms are equipped with the Century aperture cooling system.

tions from the curved surface at one end of the screen, were caught and visible on the curved portion of the screen at the other end.

Another problem that had to be overcome. As three projectors were used, three distinct pictures were projected onto the screen, each of the projectors taking care of one-third of the picture, these three pictures had to be "blended" so that the dividing lines between the pictures were not visible to the audience. The pictures thus had to overlap, but this increased the lighting of the overlapped portion. To overcome this difficulty a saw-toothed attachment that oscillates in the light beam at the gate aperture at the extreme edges of the picture was installed, this cuts down the light approximately 50 per cent at the edges, so that the overlap on the screen appears uniformly lighted with respect to the rest of the projected picture.

The projectors were built by Century, each projector fills 48 degrees or one-third of the screen. The lenses are matched lenses as to magnification, and other optical requirements. The sprockets on the projector are oversize, and the intermittent sprocket engages in six of the film sprocket holes as against four in standard projection. The film runs at 26 frames per second, it is standard 35 mm. stock with a six hole sprocket frame. The frame is one inch by one and one-eighth inch. The film is edge-guided in the projector to help avoid jump and weave in the projected picture. The film is edge numbered from the "start" mark. So that in case of film break in any one of the projectors or a break in the soundhead, the projectionist on the machine where the break occurs, threads up on any frame with an edge number and reports this number to the console operator, who passes word to the other two projectionists, who roll their individual machines to that same number on the film footage counter that is attached to each of the projectors,.the three projectors are then all restarted and all are in synchonization.

Cinerama employs Stereophonic sound, similar to that used by Walt Disney in Fantasy, sound originally picked up by the 6 microphones in recording the picture, is reproduced in the theater from loudspeakers



CURVED SCREEN for Cinerama system has end sections of vertical ribbons, arranged like slats of Venetian blind. This eliminates reflection of light from ends to center of the concave screen, which detracts from clarity of picture there when ordinary screen material is used.

placed all across the screen, and to the sides of the screen and from a speaker in the back of the theater. The placement of these speakers produces the "sound perspective" that makes voices and music come from the proper direction in accord with the action of the picture on the screen. We need not go into the subject of Stereophonic sound as we intend to devote a chapter to this important subject later.

Control of sound and picture are under constant supervision of one man at the sound and picture console, this has gain controls and patching facilities. The projectors are started remotely from this position and the light intensity of the three screens is constantly adjusted.

At the time of writing Cinerama has played to almost 500,000 people, the theater is sold out three months in advance. Newspaper critics treated Cinerama kindly most of them claiming that this was the greatest innovation in the industry since the advent of sound. However Aaron Nadell, of International Projectioinist, had the following to say in a recent issue:

The effect, as viewed for the first time and with suitable program material, is startling. "So intense is the feeling of realism transmitted by Cinerama that not a few viewers are overcome physically—the genteel term is 'nausea' or 'sea-sick'—and are compelled to leave the auditorium hastily."

This extreme result was not repeated at the October 1st matinee, but the audience was decidedly "overcome" with excitement; whistling, whooping and ultimately applauding at the opening sequence in which they seemed to be actually riding in a seaside roller coaster, looking out over the ocean, swaying and turning, climbing, and swooping in spine-tingling descent. The effect produced was not that of seeing a movie, but of being there in the darting, rocking car. The shoulders of some members of the audience could be observed to sway with the motion of a car they were not riding but felt they were. Subsequent scenes did not always reproduce the same intense realism.

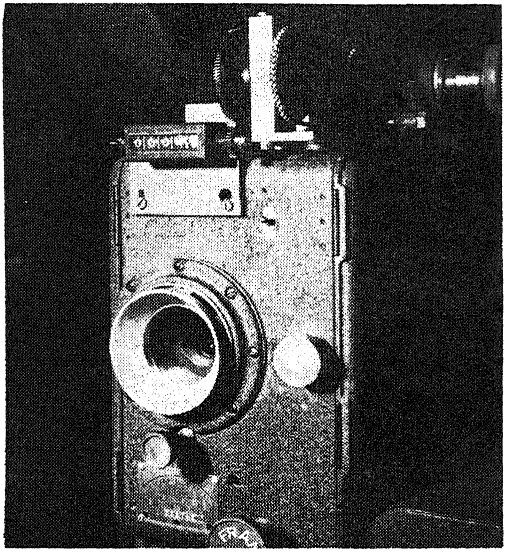
Public reaction at that first of all commercial showings was enthusiastic not only in applause, but also in conversations overheard during the intermission. They thought it was "great."

One advantage that helped produce this impression was Technicolor of marvelous quality. Another was three-dimensional sound better than ever heard in any movie theatre. During the *Aida* presentation, for example, one could close one's eyes and almost imagine that the orchestra was actually a living operatic orchestra—almost, that is, nearly but not quite together; something indefinable and slight was still missing. But of what other mechanized sound can one say as much? Coming from six different speaker systems, this sound seemed to be always at least quasi-binaural in quality; and at times it followed the action across the screen or swooped round the sides and rear of the auditorium in true stereo reproduction. Much of the uncritical audience's enthusiastic acceptance of Cinerama must be credited to truly splendid color and sound.

But if they liked it so well, what's wrong with it, if anything?

Plenty is wrong with it that uncritical eyes would not notice at first, but will waken to slowly when the novelty wears off. That no doubt is why its sponsors extended their premiere invitations to personalities who would be impressed and give Cinerama favorable publicity, but not so freely to technical people. For example: Maggi McNellis, radio commentator, interrupted her September 30th description of Fall styles in ladies' hats to announce her invitation to see Cinerama—but no invitations were sent to the Society of Motion Picture and Television Engineers. (Nor have Cinerama's sponsors ever accepted repeated invitations to present a paper on it before the Society.)

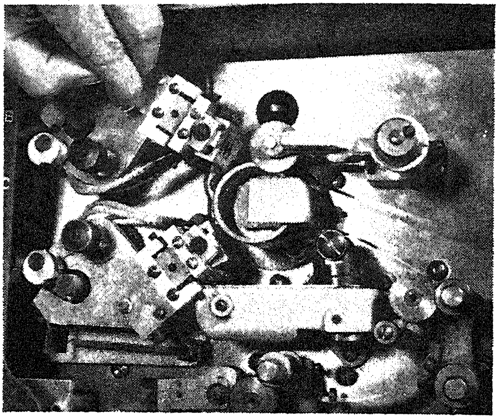
There are at least eight major technical flaws in the Cinerama process, none of which admits of ready or easy remedy, and all of which were glaringly visible even at the first commercial performance when equipment was still factory-new, and operation supervised by inventors and engineers in addition to projectionists.



FOOTAGE COUNTER on the Cinerama projection head, with a part of the synchro mechanism shown at the top.

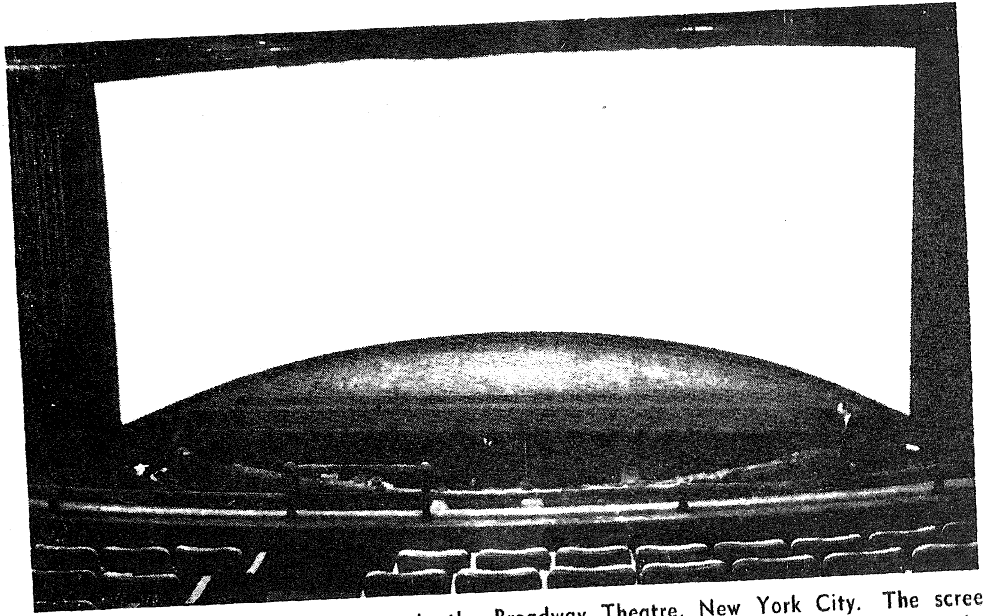
1. Horizontal lines are seldom straight. (They are projected onto a curved screen, which curves them.) The pretzel-like effect on railroad tracks was almost

grotesque. Funny, or perhaps unfunny in so serious and earnest a project, was the unhorizontal sea-horizon in the roller coaster sequence; for, while the car was rising toward the top the horizon line was a smiling mouth, corners curving up; but when the car reversed and started downward the horizon also reversed and became disconsolate, corners down. The same inevitable, unavoidable effect was also visible in other sequences, but railroad and horizon lines showed it most clearly. If Columbus had had Cinerama instead of only an egg he would have had no trouble at all proving the earth is round—one look at the horizon in the Aquacade sequence would have been proof plenty.[4]



SOUND HEADS of the Cinerama magnetic sound recording system. Mechanism has recording heads arranged in 2 banks of 3 each to record the pickup of six microphones which supply stereophonic sound for films.

2. The joints between the three component panels (frames) are not always as perfect as desired; vertical junction areas often show plainly.



Panoramic screen used for Cinerama in the Broadway Theatre, New York City. The screen measures 78 feet around the curve, 51 feet straight across the curve from end to end, and has a height of 26 feet. Three projectors, their light-beams crossing, are needed to put the Cinerama show on this screen.

3. Projector jump (vertical vibration) of the three projectors is not in synchronism. For example, during the solemn singing of *Abide With Me* one of the massive church columns was partly in one panel and partly in the other; and these two half-columns vibrated against each other, completely destroying the impressiveness of the effect, at least to one observer.

4. When one of the three projectors gets out of frame and needs to be reframed with respct to the others, illusion again is ruined.

5. The projection light on the three panels is often unmatched as to both brightness and color tone. The lagoon of Venice seemed at times to be composed of water of three different colors. And in the Edinburgh sequence the white-faced Scotch bagpiper who marched across the screen from one panel to another instantly became sunburned!

6. Whenever horizontal lines stretch across the screen so far as to pass from one panel into another and the camera is panned, a jiggle appear at the narrow area of junction. This, in combination with the projector jump mentioned above, produces some really grotesque effects. Queerest was in the airplane sequence when Lowell Thomas proclaimed: "Nobody ever saw Manhattan Island like this before." He was quite right: nobody ever saw the Empire State Building doing a jig before. Later on in the same airplane sequence the Sierre Nevada mountains danced.

7. Keystone distortion in viewing: it is obvious that to a person sitting at either side of the theatre there must be keystone distortion of all objects appearing at the same side of the screen, because that side of the screen curves toward him. This was especially visible in a choral number; the chorus divides into two groups which take up their places at opposite ends of the scene.

The group appearing at the far side of the screen looked normal to an observer in a side seat; but the group at the near side looked thin as matchsticks.

8. The peripheral vision advantage claimed for Cinerama applies most effectively to those seated up front; and becomes progressively less toward the rear of the theatre. The Broadway Theatre, New York, in which these first commercial showings are held, is an old legitimate house essentially square in shape; in a longer and narrower auditorium only a relatively small percentage of the audience would be exposed to the full effect of Cinerama.

And technically unskilled reviewers, reporting the premiere in the New York daily press, though apparently they did not note all the mechanical flaws, did comment on some; and also noted that the presentation offered only spectacular scenes, no dramatic or emotional ones.

Cinerama is not a third dimensional system, the illustration of depth is obtained by the use of the "wrap-around" screen and its extreme width of 65 feet, giving a screen picture which more approximates the human field of vision than does the standard screen with a 3 to 4 ratio. Cinerama is not for the smaller theaters or for theaters with long narrow auditoriums. The cost of the installation and opeating costs make it prohibitive for any but the large presentation type of theater, and the great loss of seating space, necessary when the equipment is installed in a narrow auditorium, means that it will be restricted to the theater with a wide auditorium.

No figures have been released as to the cost of the equipment and installation costs but it has been estimated that the installation at the Broadway Theater in New York City runs between $50,000 and $100,000. Approximately 400 seats had to be removed at the Broadway Theater because of the installation of the three projection booths.

CINEMASCOPE

The proposed Fox CinemaScope is a modified Cinerama. However, there is quite a difference as to the equipment required in making the pictures and for projection. Only a single camera is used in the photographing of the picture, and the only change in this camera is the addition of a special "compression" lens, which compresses the picture, in one direction, on the film.

The film is then handled in the customary manner through the stages of recording, processing, etc., and is treated just the same as the old flat picture has been in the past.

For projection in the theater, the two projectors are fitted with a special "expansion" lens, this is in addition to the usual objective lens now used. This lens expands the compressed picture of the film, onto an expanded width screen. Probably the screen will be in the ratio of 2 to 1, or maybe 2½ to 1.

Only one projector is in operation at a time, as in standard projection, the usual change-over being necessary between each reel of film. No changes are necessary to the projectors, and nothing has to be added, except the new expansion lens.

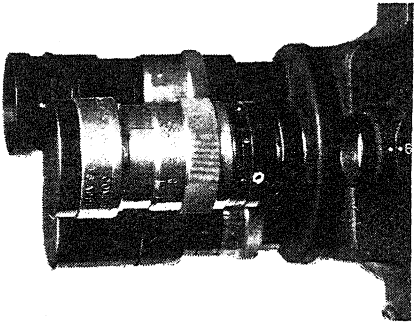
The audience will not have to use glasses or any other mechanical viewing device, while watching the screened picture, and this means that the system is NOT truly third dimension, but will depend upon the much larger sized screen, the change in screen ratio, and the use of stereophonic (directional) sound, to help create the illusion of depth in the minds of the audience.

The use of stereophonic sound, will call for the installation of a number of speakers placed in different locations throughout the theater auditorium, most of these will be installed right across the entire wide screen, one or two, down the sides of the theater auditorium, and maybe one speaker in the rear of the theater. The multiple speakers will mean that a special sound track will be made for each picture, so that the correct sound can be fed into the respective speaker for which it is intended, and this will give sound perspective.

It will be well not to confuse this CinemaScope process, with the first two stereoscopic releases of 20th Century Fox, as Fox is using the Natural Vision process for the filming of these two pictures, and it will be necessary for the audience to wear the polaroid glasses to view these pictures. The first release made by the CinemaScope process will come later.

The installation of an extra wide screen will be necessary with CinemaScope, and these screens will have to be the highly-reflective type such as the metallic screens. The extra screen width will call for an increase in light output at the arc lamps.

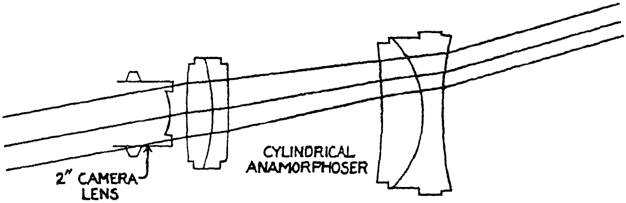
The whole system of CinamaScope is based on the use of a cylindrical compression lens, called an anamorphoser, when making the picture, and the use of a similar lens when projecting the picture. The use of this type of lens was considered by the industry over twenty years ago, to restore the aspect ratio of the screen picture, when its proportions were cut, because of the filming of the sound track on the margin of the film, thus reducing the space in each frame, for the photographic picture. As a matter of fact this same type of compression lens was considered in the very early days of motion pictures, to help save film cost. Back in 1933 H. S. Newcomer, a well-known consulting engineer of New York City, who had given a great deal of study to this type of lens, prepared a paper dealing with the subject of an anamorphoser lens for use in the making of motion pictures; this paper is most timely today, and we here present excerpts from this paper.



Cylindrical anamorphoser:

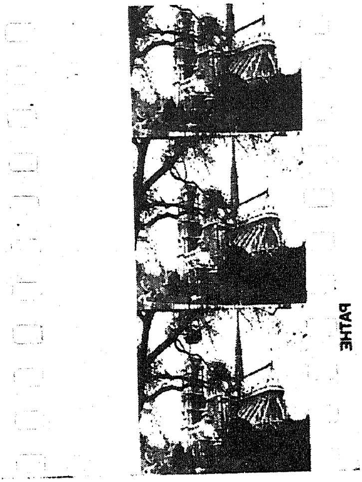
From an optical point of view, standard film has many advantages, and the importance of the dimensions of the frame in forming suitably sharp images becomes apparent only after one has had an opportunity to study the performance characteristics of motion picture lenses. This not only has an important bearing on the dimensional relations obtaining in present-day practice, but it very seriously handicaps the use of wide film and affords a considerable advantage to optical compression as a means of obtaining laterally extended screen images.

Thus, from the point of view of sharpness of image, the results attained by the compression or anamorphosing objective are superior to those afforded by wide film. This advantage is by no means the sole merit of the method. The anamorphoser comes into play only twice in the entire sequence of operations from the taking of the picture to its projection on the screen; namely, at the beginning, when it is placed in front of the ordinary camera equipment used to take the picture, and at the end, when it is placed in front of the projector to expand the picture on the screen. In all the many stages of processing and handling, the film is treated as ordinary standard film, and the tremendous expense involved in providing special equipment for processing, packaging, and projecting wide film is all avoided. The anamorphoser permits wide screen pictures of excellent quality to be shown interchangeably with standard pictures, and the method may be used for either whole features or particular scenes as desired. Contrary to current opinion it is extremely easy to mount cylindrical compression systems on both cameras and projectors.

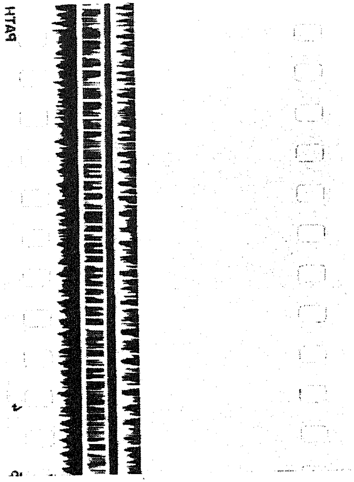


A cross-section of a fully corrected anamorphoser.

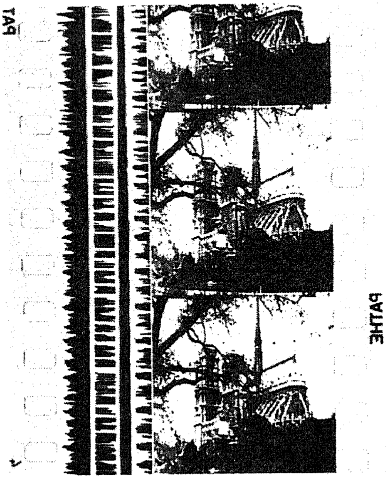
In taking the picture, the effect of the anamorphoser is to compress a wide picture into a relatively narrow space. The compression is produced by a device that acts like an inverted telescope, but in one meridian only. The cylindrical anamorphoser is composed in its simplest form, of a positive and a negative cylindrical member with axes parallel and arranged in the manner of an ordinary opera glass or Galilean telescope. The anamorphoser is afocal; hence its interposition in front



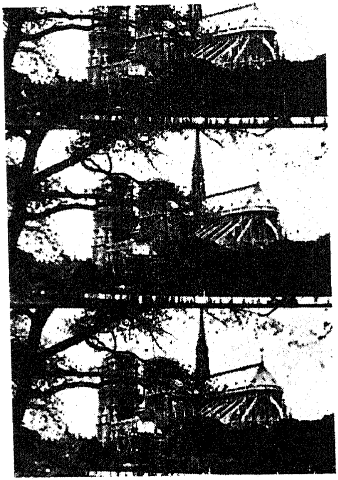
Negative made with an objective of 50-mm. focal length and an anamorphotic system that doubled the field.



Three sound tracks united on one film.



Combination of the anamorphotic image and the



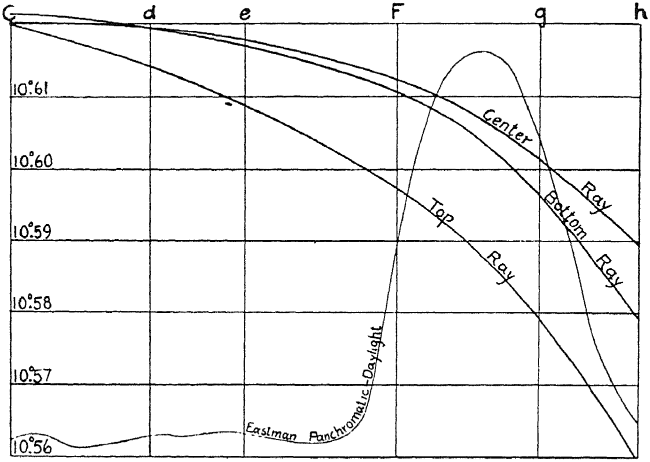
when restored to its normal proportions.

of the ordinary camera or projection lens does not alter the focus of the lens. During the photographing, the anamorphoser merely compresses the image of the laterally extended scene into a narrow film space; during projection it expands the projected image to an increased width on the screen.

The cylindrical anamorphoser is not a recent development, even in motion picture work. Ernest Abbe many years ago described all the types used today. At the beginning of the present motion picture era, Zollinger proposed to use them to compress the image and save expenditure for film. It was only recently, however, that serious attempts were made to rid these anamorphosers of the considerable color and other imagery defects which they exhibited and to correct them to the degree required in motion picture work. Many attempts at improving the photographic quality of these systems have not been very sucessful. Only a short time ago Mr. H. W. Lee, in speaking before the Royal Photographic Society, called attention to the fact that "the designing of these systems was exceedingly laborious, and the manufacture of deforming systems with cylindrical lenses far more difficult than of optical systems with spherical surfaces."

However, as is often the case, once a satisfactory solution has been obtained, the problem appears much simpler. As a matter of fact, if certain features of design be adhered to, features that involve among other things the relative indices of the glasses used and the orientation of the cemented surfaces and the cambrures of the elements, an extremely simple system that is unusually free from aberrations of every sort can be designed. Figs. A and B show, respectively, a photograph and a cross-section of a fully corrected anamorphoser, and serve to illustrate its simple and compact construction. This anamorphoser is used without any supplementary correcting system, none being necessary.

The aberrations of cylindrical systems of this sort are, in a way, analogous to those of spherical systems. In correcting for the imagery at the central portion of the field, once axial astigmatism is obviated by proper spacing arrangements, it remains only to rid the system of spherical and chromatic aberrations. This may be done by correcting each individual member separately. The residual secondary spectrum, and the zonal errors are then of similar magnitude and opposite sign, so that the assembled system may be exceptionally well corrected for axial image points. In fact, it has been found that by thus largely ridding each member separately of spherical aberration, the zonal spherical aberrations of the system as a whole may indeed be made so small as to have a maximum value of one part in thirty thousand, equivalent to a longitudinal focusing error of one part in one hundred and eighty thousand for an associated



50-mm. camera lens. The paraxial color focal difference in the spectral interval *C* to *F* may be one part in seven thousand and the zonal color differences one part in ten thousand, corresponding, respectively, to one part in forty thousand and one part in sixty thousand for the associated 50-mm. lens. These are, of course, fantastically and unnecessarily small errors.

This leads us to a consideration of the color correction for marginal or extra-axial points of the image. It has been found possible by suitably constructing the two members, to eliminate astigmatism and coma along inclined rays; in other words, to make all the rays of any entering bundle of parallel rays traverse the objective and emerge from it still parallel. This parallelism can be made practically absolute for all the ray of a particular bundle, provided the light is monochromatic. But if the objective be composed, as just described, of members individually fully achromatized in the usual manner so as to be, as far as possible, free of color focal differences along the axis, there remains an appreciable lack of parallelism of the different colored rays of an inclined bundle, and hence a color fringe in the marginal areas of the picture.

The curves show an angular emergence difference for the spectral interval *C* to *h* of 0.06 degree, corresponding to a diffusion circle of 0.035 millimeter for an associated 50-mm. camera lens, the angle being two-thirds as large on that side. At an inclination of 10.5 degrees, that is, for a point near the margin of the picture, the difference is greater, and the diffusion circle is about 0.06 millimeter in diameter. Although the actual effective error is somewhat less than this, nevertheless it is added to the relatively poor marginal performance of the camera and projection lenses, and therefore must be reduced.

There is an unusual and interesting method of eliminating this large marginal color error, namely by only partially achromatizing each of the two members of the anamorphoser.

Despite the existence of only a partial achromatization along the axis of each of the two members, the objective as a whole yet has a very satisfactory paraxial nd spherical color correction, one part in seven hundred and one in a thousand, respectively. The resulting diffusion circles for an associated 50-mm. camera lens are less than 0.002 millimeter in a diameter, a value that, as will be seen, is too small to produce any deteriorating effect on the quality of a motion picture image.

Since the anamorphoser is afocal, its relative openings depends only on its absolute size. It is, in fact, convenient to choose the size so as to reduce the aberrations considerably below those of the spherical objective with which the anamorphoser is associated. The anamorphoser has, therefor, an almost negligible deteriorating effect upon the image. In fact, the very slight effect observed must be attributed almost entirely to the interposition of the four air-to-glass refracting surfaces. It amounts at the most to a difference of one stop; and since motion picture lenses are now available that are appreciably more than this amount superior to most motion picture lenses now in common use, it will be obvious that one can obtain all the advantages of the anamorphoser for the production of wide screen pictures and yet retain the quality of picture to which the critical observer is now accustomed.

Except for the slight effect of surface loss, the anamorphoser does not increase the required exposure time. On projection, there is a light loss due to the expansion, and which is proportional to the expansion. We have experimented until we can print anamorphosed film so that the projected image appears as brilliant as ordinary screen images. Before this result was accomplished, it was found possible and practicable to increase the arc current until anamorphosed and ordinary illumination of the screen, projected consecutively from different machines, appeared equally brilliant.

The cylindrical anamorphoser consists of a positive and a negative member so spaced as to give an afocal combination. The axes of the cylinders are parallel; in fact strict parallelism is essential.

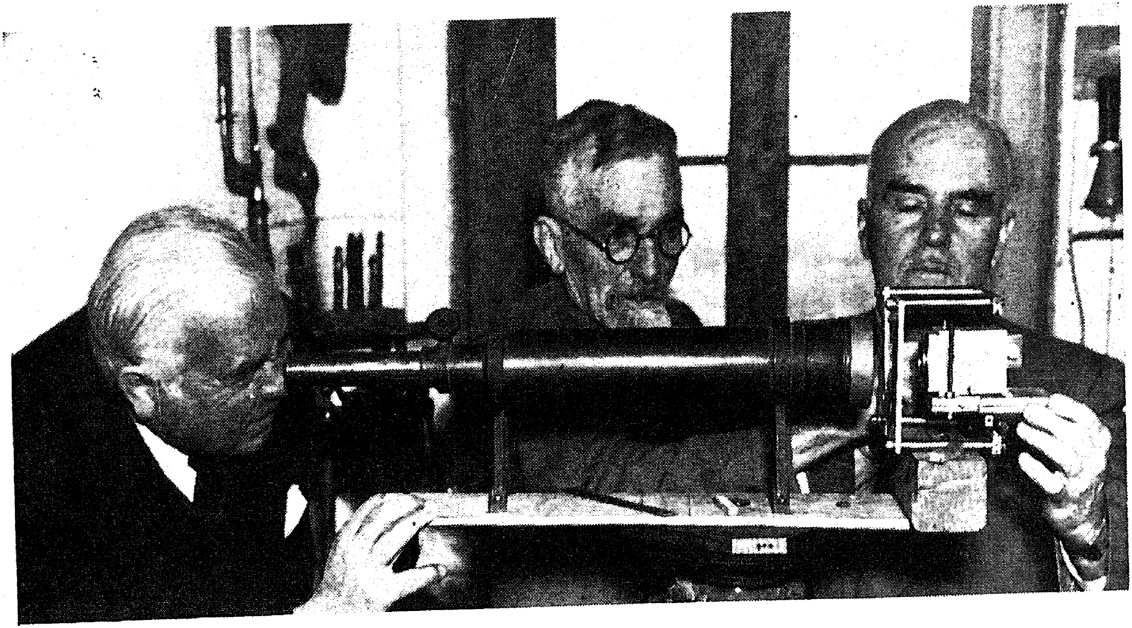
The allowable errors in alignment are almost infinitesimal, but mechanical and optical means for rapidly attaining and maintaining suitable alignment have been devised, and have solved what at first seemed to be an insuperable obstable to the development of a good objective. Similarly, means have been found of grinding and polishing cylindrical surfaces so that they can be made as easily as spherical surfaces and, as with the latter, to any degree of perfection that seems necessary and desirable. Their manufacture is not in any sense a hand process. The quality improves when the lenses are made in series.

Present-day motion picture photography and projection make demands on the optical equipment that can be properly understood only when three independent stages of the image-reproducing process are analyzed and subjected to quantitative measurement and interpretation. Thus we have first to consider the quality of the image on the negative film, an image that is carried essentially unchanged to the positive film. Then the image must be projected by means of an optical system that has, as we shall see, certain inherent limitations. Lastly, the eye perceives the screen image and requires, for a subjective sensation of sharpness and brilliance, that the blurring of the details of the image shall not exceed amounts that we shall later discuss and correlate with the definition available. As the first step we shall consider the photographic image.

Practical studio lighting conditions and emulsion speeds require the use of relatively large aperture lenses, between *f*/2 and *f*/3. This means that the apex of the cone of light forming a point image on the film embraces a rather large angle, and when not focused on the film casts thereon a circle of diffused light of appreciable size, a size also proportionate to the distance of the apex of the cone from the film. In order, therefore, that there may be a reasonable depth of focus and sharpness of image, the focal length of the lens must be short. This necessity is not avoided by using larger film.

The average focal length used for general purposes is 50-mm. or 2 inches. Shorter focal lengths are frequently used, for instance $1^3/_8$ inches; but the ability of most lenses to cover a 1-inch field at a 20 degree semiangular opening with sufficient sharpness is partly due to the absolute decrease in the dimensions of the marginal imagery errors. A 2-inch lens covering a 1-inch field has a semiangular opening of 14 degrees. A discussion of the characteristics of the images formed by such lenses will serve to set forth the conditions under which motion picture lenses operate.

It has not been an easy problem to design lenses that will give satisfactory results under the conditions obtaining in motion picture photography. W. Merte discusses briefly the difficulties with which the designer of such objectives is faced. One of the methods of approach to the problem is to modify the Petzval objective so as to flatten its field. As is well known, this objective in its original form has a large aperture and an unusually sharp central definition for a lens of such simple construction. The definition, however, rapidly falls off and is unsatisfactory even for short focal lengths at the margin of a field subtending a greater semiangular opening than about 7 degrees, requiring thus a 4-inch lens to



THIS IS THE CINEMASCOPE that Spyros Skouras, 20th-Fox president, left, and Earl I. Sponable, director of research, right, are looking at.

cover a standard frame.

A second modification is obtained by placing a strong collective element in front of or behind suitably designed Taylor triplets.

A third modification, semisymmetrical in type, is based on the old Rudolph Planar which, in turn, was developed after Alvan Clark's lens of 1889. Each half has a strong collective element in front of a compound dispersive element.

Another type is derived from a symmetrical lens by introducing into each half a dispersive meniscus turned convex toward the diaphragm. Such lenses having large apertures have been widely used for amateur photography, but they cover only a small field and show considerable spherical aberration.

Another class of objectives deserving mention are those triplets that have been redesigned to increase the opening to *f*/3.5 or more.

The quality and suitability of any of these lenses is in part dependent upon the curvatures of their focal surfaces, their spherical aberrations and their sine condition errors.

The rate of deterioration of the images with angle is for many of these lenses such as to make the images unsatisfactory when the angle is more than 10 or 12 degrees unless the focus is very short. The maximum field satisfactorily covered by short focus wide aperture lenses is 22 degrees, (28 millimeters at a focal length of 35 millimeters), and then only with a certain loss of quality which is noticeable on projection if details are to be pictured.

When the focal length is increased to 50 millimeters, the standard movietone frame has a horizontal semiangular field of about 11½ degrees, which is about the limit to which most lenses still give sufficiently good marginal definition not to detract from the quality of the picture. The best lenses will cover satisfactorily somewhat more than this, but even on the new 50-mm. wide film the angle is 5½ degrees greater, and then the lenses available are either appreciably poorer at the border or show an intermediate zon of blurring. The old 70-mm. wide film carries the field clear out to 25 degrees; and it is obvious from the data given here, as well as from practical experience with such film, that no lens covers this field with anything approaching the definition attained with standard film.

Thus, a careful study of the properties of the principal sharply imaging motion picture lenses not only shows their individual points of superiority and the absence of a "universal" lens, but makes it quite clear that definition to the degree now attained with standard film can not be attained on substantially larger areas if equal lens speeds are to be used. On the other hand, wider pictures can be optically compressed satisfactorily into the area in which good images are obtainable.

Several wide film pictures were shown in 1930. Opinions as to the sharpness of the images in these pictures vary with the interest and attention of the observer and with his skill in taking account of detail and contrast as they affect apparent definition. Clever composition and lighting play an important role in the appearance of such pictures. Certain of the wide film pictures shown were very objectionally lacking in portrayal of detail. They all showed distinct loss of definition in the outer portrayal of the picture.

It seems hardly necessary to mention here the very poor results obtainable when wide screen pictures are attempted when using reduced film images of modified shape blocked out on standard film.

When it comes to projection the same or greater difficulties present themselves. The focal lengths are longer, 4 to 7 inches, and in order to obtain, with a suitable aperture, the required high degree of central definition needed for such long focal lengths, it is necessary to use lenses of the Petzval type having notoriously limited angular fields. The greatest volume of light is probably confined to an *f*/3 projection aperture, and with such an opening the central images of the best Petzval lenses are on direct visual examination somewhat less sharp but approximately the same as those of the motion picture lenses just described.

The actual sizes of the diffusion circles of the Petzval lens have been the subject of exhaustive mathematical analysis.

As is well known, the expansions of expressions for the aberrations of spherical objectives contain only odd order terms, and it has not yet been possible to derive solutions in which fifth or higher order terms are retained. Probably such derivations are beyond the capacity of the human mind. They seem to be unnecessary when certain restrictions on aperture and curvature of glass surfaces are made.

The motion picture lenses of larger aperture, having, as some or all of them do, large curvatures of the glass surfaces, represent empirical solutions of the problem controlled by laborious trigonometric calculations. While generalizations should not be made, it is probable that the more or less uniformity in the marginal image defects shown by the best of these lenses is an expression of the minimal expectable residuum of third and fifth order aberrations. Thus, where large openings and a high degree of central definition are required, the further addition of surfaces has, as we have seen, reduced the aberrations outside the axis so as to extend the field slightly and at the same time give the advantage of increased openings with practical limits of about *f*/2.3.

Every useful objective must be achromatic, *i. e.*, color corrected for two particular wavelengths. The residual lack of color correction for the intervening wavelengths is called the secondary spectrum of the lens, and in the useful spectral interval reaches a maximum at a certain wavelength. This color error of the astrophotographic objective is for the center of the field the worst error that it has; and however small other errors may be, they will be hidden in the color diffusion circle. The latter, therefore, even if somewhat better tolerated, furnishes a criterion for the measurement of other errors.

It is hardly necessary to mention that objectives comprised of thin unspaced glasses, as in telescopes, show considerable astigmatism and curvatur of the image fields.

By separation of the elements, curvature of the field and coma can be eliminated.

In motion picture projection, the size of the field to be projected remains constant regardless of the focal length of the lens; hence the designers of projection lenses have been under no obligation to make all focal lengths geometrically similar, such as is generally done in the case of ordinary photographic lenses where plate size is proportional to focal length. Likewise, the focal surface characteristics of certain motion picture camera lenses vary with the focal length.

The Taylor type of objective, with three spaced elements and somewhat greater curvatures of the glass surfaces, can be designed with appreciably smaller diffusion·circles due to astigmatism, but the secondary spectrum increases.

The center of a sharp motion picture negative or positive will show distinctly letters formed by lines 0.01 to 0.02 millimeter wide. Letters that are 0.1 millimeter high on the film may be nearly illegible without one's noticing loss of detail when the picture is projected. In a theater with a 100-foot throw and a 25-foot picture, such a letter is about 30 millimeters high on the screen. At a distance of 40 feet from the screen, the average person with good vision can read letters 20 millimeters high, but he does not try to exercise his vision to this extent and cannot distinguish the courser details of the letters until they are about 80 millimeters high, the distinguishable details then having dimensions of about 10 millimeters.

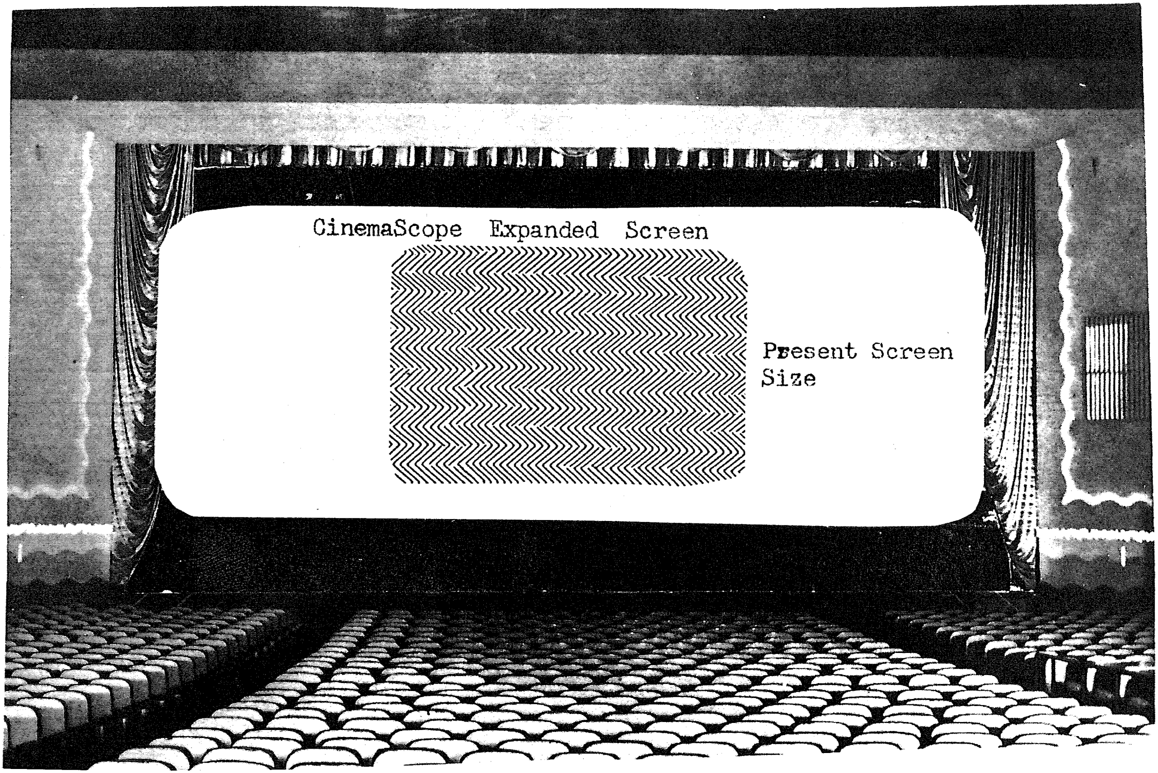
Probably the average critical observer does not notice extreme haziness of letters that are 0.1 millimeter high on the film. Even their being illegible may not be noticed, so that what has here been called a 0.004-mm. diffusion circle would be just tolerated at the center of the picture. This size of diffusion circle would be quite satisfactory at the border, and nearly twice that size would be tolerated provided projection did not make matters worse. The figure 0.055 millimeter given above for projection is perhaps not to be added in its entirety to the size of the diffusion circle at the margin of the negative image, but the combined effect must be just about what has been considered allowable.

In order to visualize the meaning of these figures one might hold an inside page of the New York *Times* at arms length. The "want ads" will be just legible. The individual letters, even if jumbled, would also be legible if they were distinctly formed. Such letters correspond to the 20-mm. screen letters of the above example or to 0.07-mm. film letters. Even the very best lenses will not reproduce such characters sharply; and, indeed, the reader in looking over the newspaper at arms length does not attempt to notice print of that size. He is not even attentive to the ordinary newsprint, which is half again as large. On the other hand, letters 40 millimeters high on the screen — 0.14 millimeter on the film, for which our diffusion circle is 0.05 millimeter—correspond to minor titles in the news column, which may very well be read if the attention be attracted to them. In sharp film they will be legible, but not as clear as in the newsprint analogy. The 80-mm. screen letters, appearing sharp or at least clear, as they do in good pictures, correspond roughly to the column headings in the newspaper. They must appear distinct if even the casual observer is to be satisfied.

Anamorphosed or compressed negative motion picture images are obtainable in actual practice in which there is perfect definition of letters appearing even at the margin of the picture and of size down to 0.14 millimeter high on the film. Such letters to be sharp mean diffusion circles appreciably less than 0.04 millimeter on the film. In practice, letters that are 0.04 millimeter high on the film are illegible, the amount of illegibility fixing the diffusion circles in the central area at about 0.02 millimeter.

It should be remembered that the projection lens works at twice the focal length of the typical camera lens we have been considering. The projection lens, however, when used on standard film, is required to cover at most a semiangular field of only 5 degrees, and under such conditions does fairly well. It is extremely poor at 10 degrees and useless beyond and, indeed, before 10 degrees.

Where wide angle projection is necessary, it is possible to better the performance of the Petzval lens. Reference will not be made here to back screen projection where both the focal length and throw are short and the screen image less sharp than in standard practice. We have seen that attempts to improve lenses that perform similarly to the Petzval lens have resulted in the development of the present motion picture camera lenses. In the case of the best motion picture lenses above described, working at *f*/2.3 or *f*/2.7 for 4½-inch focus,


CinemaScope Expanded Screen
Present Screen Size

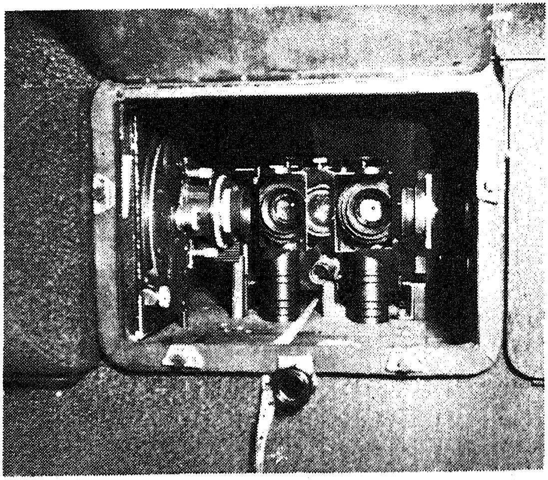
the diffusion circles at the center of the image for the visible spectrum are about 0.004 to 0.01 millimeter. Letters 0.05 millimeter high on the film are quite legible and sharp. On the other hand, at a semiangular field of 8 or 10 degrees and for this focal length, the diffusion circles are about 0.04 millimeter or more.

It has been shown that it is not possible to take, nor is it feasible to project, wide screen pictures under conditions that will result in images half as good as those now obtained. On the other hand, wide screen pictures of a quality comparable with the present standard pictures may be obtained by using an anamorphoser. The simplicity of this method of projecting wide screen pictures hardly needs to be elaborated upon. One further advantage of the anamorphoser should, however, be mentioned. This is an optical advantage, increasing the depth of focus, and hence the general sharpness of the images, over and above that of ordinary pictures.

A cylindrical anamorphosing system magnifying 50 per cent in one meridian increases the depth of focus in that meridian by 100 per cent. If the anamorphoser be focused for a given object distance, then the interaction of the two elements of the anamorphoser on light coming from points nearer and further away is such as to approximate the corresponding camera lens images and bring them nearer the image plane for the mean focus. The amount they are moved toward this plane is exactly one-half the focusing difference for the camera lens.

For reasons associated with the nature of image formation in the eye, the effect of natural diagonal astigmatism, the apparent gain in depth of focus is practically equivalent to these figures. In fact, all who have studied anamorphosed wide screen pictures have noticed this effect. Similarly, for physiological reasons, the expansion in one meridian only does not increase the graininess of the projected image. The pictures are as smooth and free from graininess as unexpanded pictures two-thirds the size.

Thus, the optical and practical advantages of the anamorphoser are real and important. Its use will greatly facilitate the introduction of wide screen pictures with their many advantages for improved pictorial effect, pleasing proportions, and increased number of full-length characters on the screen. In the latter case, the increase in size of the object imaged, an increase allowed by the altered proportions of the frame, still further increases the apparent sharpness of the picture. This effect can not be ignored, particularly in color photography, where there is a certain inherent lack of definition that this application of the anamorphoser will overcome, and without interfering with the technic of the color process.



NATURAL VISION

The camera used in the making of Natural Vision Pictures, is really two cameras joined into a single unit. Each of the two camera's photographing onto a seperate 35 mm film stock.

Natural Vision uses variable parallax as the basis of their system.

The camera's are 35 mm Mitchells so mounted on the base that the objective lens of one camera faces directly the lens of the other camera. Just as though, one of the camera's was taking the picture of the lens of the second camera, situated in between these two lenses is a prism, or mirrors, which splits the light beam, sending into one camera the picture which would normally be seen by the left eye, and the other beam which would be seen by the right eye into the other camera. This prism or mirror, is fitted with micrometer adjustments, so that the beam can be correctly reflected into the proper channel for each camera.

There are also controls on the camera which enables the operator to make the fine micrometer adjustments for the parallax correction prior to the photographing of each scene.

Other adjustments change the viewing angle of one of the cameras. Each camera is fitted with a single lens, the use of the standard turret and multiple lenses has to be dispensed with, the single lens is changed as needed from time to time, in the making of the picture. It is absolutely essential that the two lenses used at a time, one in each camera, be carefully matched for optical characteristics.

The two cameras are fitted with a viewfinder so that the cameraman and other studio personnel can watch the photographing of the picture, while the scene is actually being shot.

In shooting the three dimension pictures, a new technique must be used, the sets and placement of the actors must be such as to avoid false perspective and distortion. The "locale of action" for each scene must be kept within certain prescribed bounds to secure the proper stereoscopic effect when the picture is projected.

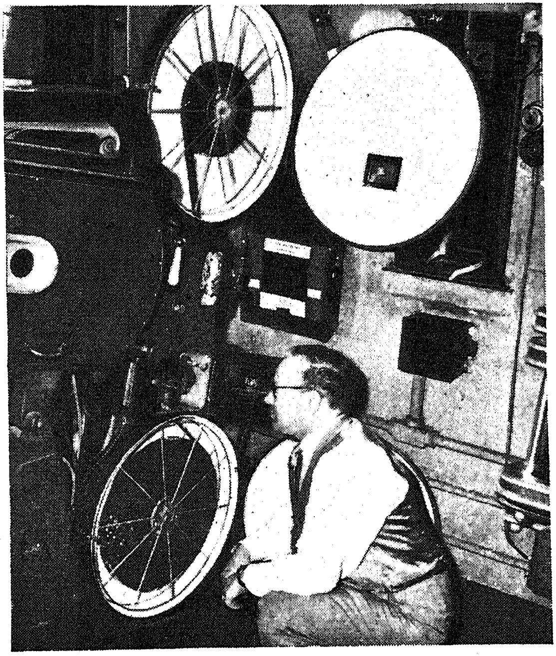
In the projection of the Natural Vision picture, two projectors are used, both running simultaneously. One projector, is threaded with the film made by the left eye camera, while the other projector is threaded with the film made by the right eye camera. Both pictures being superimposed on the theater screen.

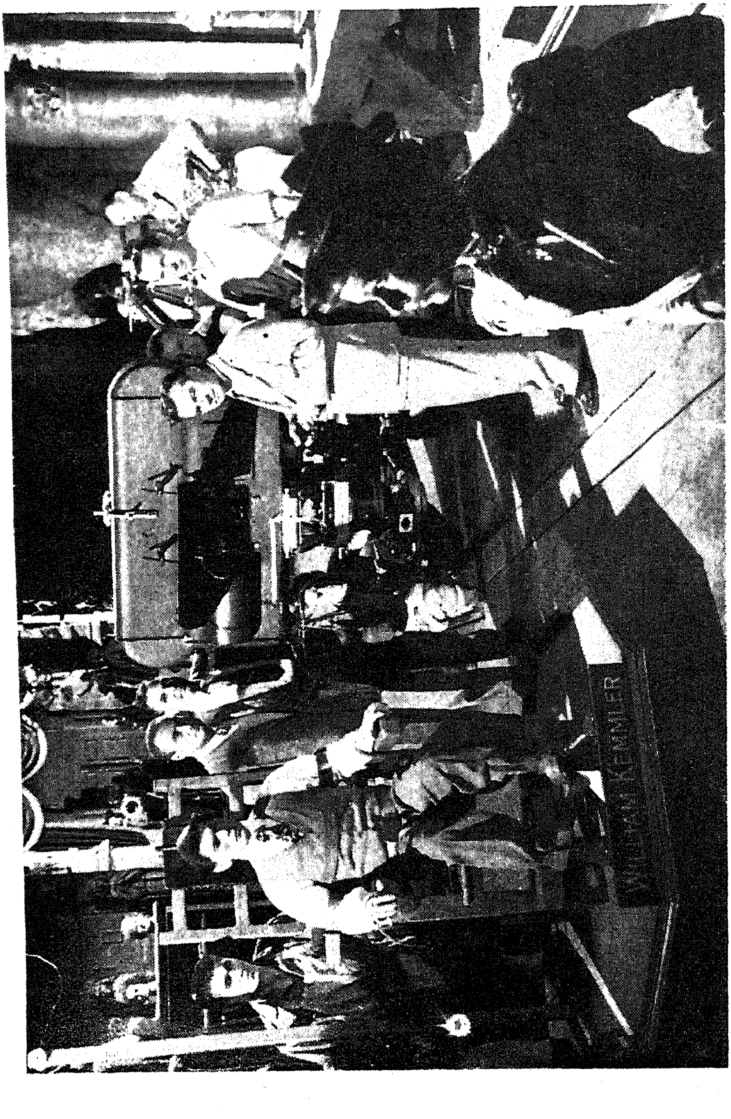
The pictures must be projected through Polaroid filters, a special filter being necessary for the projector on the left and a special filter for the one on the right. These filters are marked, so that the proper filter can be installed at each projector. These filters are at present being installed in the projection ports in the booth. It is necessary that great care be taken in the installation of these filters, instructions are being shipped with the equipment, and these instructions will have to be closely followed.

White light from the projector, should never be projected through these filters, as this will render them useless. A second set of filters should always be kept on hand to be used in case of any trouble.

These filters like the glasses worn by the members of the audience are made by the Polaroid Corporation, and are the invention of E. H. Land of Boston.

Ordinary light can be said to vibrate in all directions at right angles to the direction in which it is travelling. Polaroid is made up of a multitude of submicroscopic crystals, each having polarizing properties, all lined up perfectly and immovably embedded in a transparent sheet. The effect of these crystals is to absorb vibrations along one of their axes. Such alterations of light are not obvious to the viewer unless he have a second piece of Polaroid with which to observe it. However, if a second sheet of Polaroid is placed in front of the lighted area, all goes dark when the axes are crossed, or light when the axes are parallel. (Incidentally, when a cellophane design is placed between the two pieces of Polaroid, this colorless, transparent material lights up with colors that can be reproduced at will and that are permanent; and as the front Polaroid screen is rotated, the colors gradually change

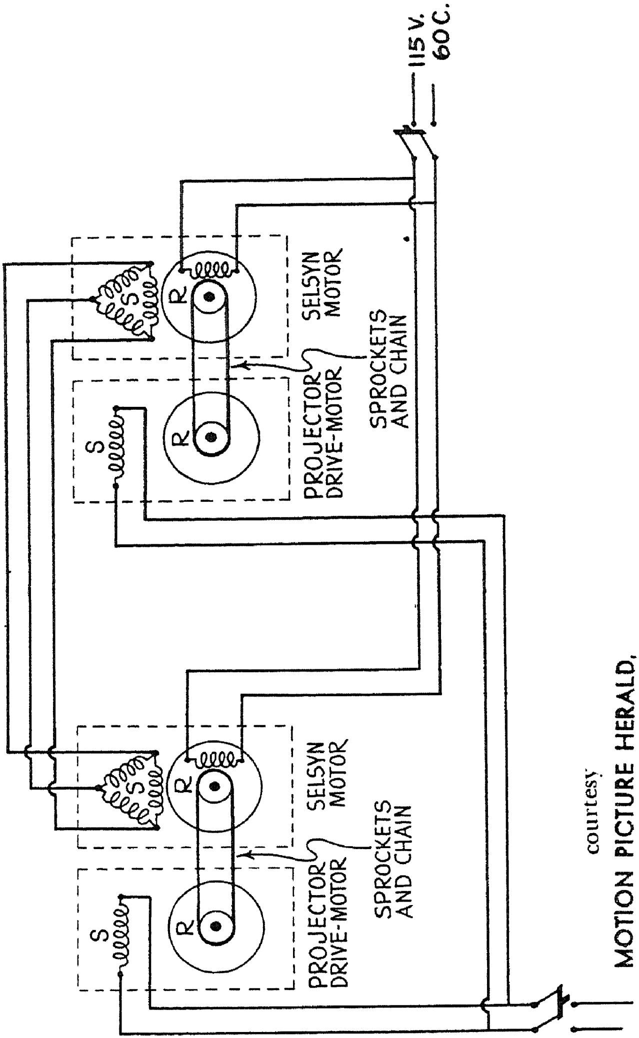




On the set of Warners' "House of Wax," Natural Vision three-dimensional film to their complementary opposites. For the first time it is possible to have large designs or plain colored areas that are changeable at will, permanent, and reproducible.) Now, if the front Polaroid screen be removed and the observer put on his Polaroid glasses, his left eye sees the screen clearly; the right eye view is dark. If he tilts his head far over to the side, or removes the glasses and holds them vertically, he will see that now the right eye is transparent and the left eye dark. When taking the picture no such material was used. This same device used in front of the projector, or one similar to it, is mounted upon the camera to take two pictures eye-distance apart and place them upon the film side by side. These two pictures are projected again through this device, and upon leaving the device the two eyes are again separated. At this point each eye has a piece of Polaroid placed in front of it. The right one transmits horizontal vibrations and the left one vertical, exactly as the glasses are arranged. The right eye sees the right-eye picture but not the other. Conversely, the left eye sees the left-eye picture and not that intended for the right eye. The essential condition that each eye see its own picture and only its own picture is achieved. There is nothing to be adjusted mechanically or otherwise.

The two projectors must run in exact synchronism, so the projector driving units must be interlocked. This can be accomplished either by an electrical interlock using selsyn motors, or by a mechanical interlock. The electrical interlock using the selsyn motor is the most efficient and least likely to give trouble, as a matter of fact it is practically fool-proof.

The regular projector motors are used, and these are each coupled to a selsyn motor. The duty of the selsyn, being to keep the two regular motors from



courtesy
MOTION PICTURE HERALD,

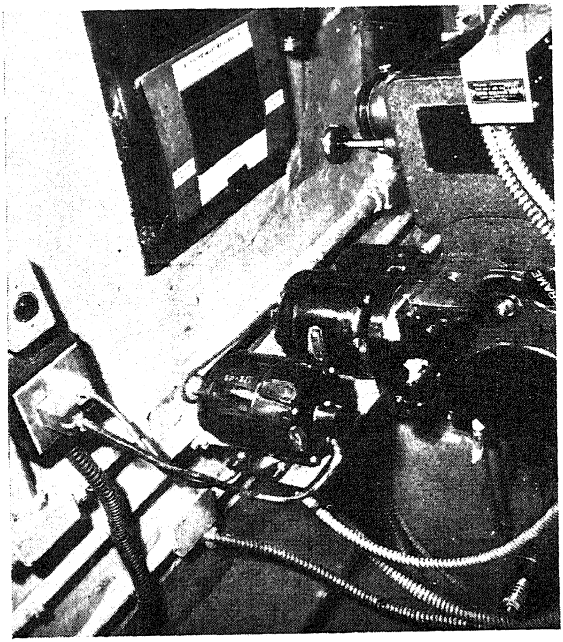
drifting apart, so that the two remain in step and both run at exactly the same speed, thus keeping the two projected films in exact synchronism. A single switch operates the starting and stopping of the four motors.

Because the two projectors are used at one and the same time for the showing of the films, it is impossible to run a continuous show. There must be breaks for rethreading the film and for arclamp retrimming. The film therefore comes on oversize reels measuring 23 inches, and holding some 5,000 feet of film. Thus the show can be run with but one intermission midway during the program. An intermission, will of course, also be required between each complete show. To accommodate these oversized reels a new 24 inch upper and lower film magazine must be installed, and this may mean that the projector will have to be re-located, or built-up, in the booth, to give clearance for the large magazines.

The rewinder too, will have to be raised, so as to take the new size reel. Another factor that must be taken into consideration on the installation of any type third dimension film, or for that matter, the expanded screen type also, is the question of screen light.

The Polaroid filter, must be placed in front of the projector objective lens with its surface at right angles to the lens. A line drawn through the optical train of the projector, should pass in the exact center of the filters. These filters are of a light-polarizing material. The light from the arc, passes through the optical train of the projector, and leaves the projection lens, unpolarized, the light after it passes through these filters is polarized at a 45 degree angle. The filters will only transmit light in the plane or axis of polarization. The plane of polarization for the left hand projector is 45 degrees from the horizontal sloping to the left, while that from the right hand projector, is 45 degrees from horizontal, but sloping to the right.

Filters must be carefully installed in the projection ports, they must be kept cool, as otherwise they may bulge and this will render them useless, they must be kept clean and free from dust. A special "static" brush can be obtained for the purpose of keeping the filters free from dust.



The installation of the polaroid light filters in the projection ports, which cuts the light beam from the projector, means a light loss of something between 50 and 60 percent. An additional loss is apparant to the audience, because of the wearing of the polaroid glasses.

The loss of this light, may mean that the arc amperage will have to be increased, and in those theaters that are now using maximum amperage output, this problem may require the installation of entirely new designed arclamps, the present maximum amperage output cannot very well be increased with the present type arcs, due to the excessive heat on the film at the gate aperture.

This too will call for higher power generators, new rectifiers, and perhaps a rewiring job to take care of the larger load.

Every precaution should be taken by the projectionist to see that there is no undue loss of light anywhere in the projector optical train. Only 2 and one-half size lenses should be used, and these should be of the coated type. It is all important that the two objective lenses are correctly optically matched as to magnification factors and color values. A mismatch in the lenses, a difference in color values or light values between the two projected pictures, will mean eye strain for the audience, and a probable loss of theater patronage.

The use of a highly reflective screen, such as the metallic surfaced screen, is required for third dimension pictures, and where this type of screen is installed in place of a matte type screen, a decided brighter picture will be the result, and this will especially hold true in theaters with narrow auditoriums. In theaters where a matte surface screen (a light diffusing type) has recently been installed, it may be possible to have the screen treated with a metal coating to save the expense of installing a new screen.

We have already explained that an intermission midway through the program will be necessary for the retreading of the second half of the program. This time will also be necessary to give the projectionist time to recarbon his arcs. The use of the 5,000 feet reels, means that the arc lamps must burn continuously for approximately one hour. To the running time of the film must be added the two minutes time necessary for the "burning-in" of the new carbon trim, and the 10 percent safety factor, when figuring the retrim.

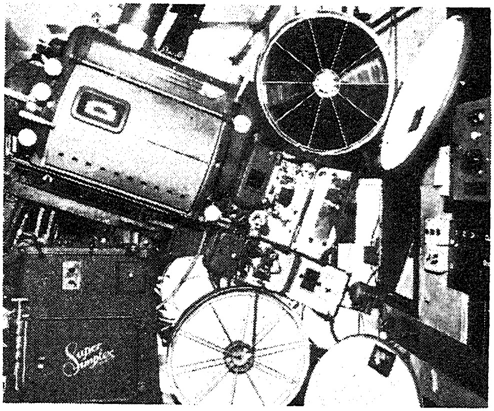
A 20-inch trim of carbons will burn continually for a full hour at 78 amperes, when using 9 mm positive and a 5/16th" negative. Or the same 20-inch trim will burn a full hour at 95 amperes when using 10 mm positive and 11/32nd negative. A constant check of the arcs will be necessary all during the running of the film program to keep the light values at each arc uniform and to watch the color values of each of the arcs.

A 9-mm positive can be burned at 82 amperes and a 10--mm positive at 98 amperes for 50 minutes, but to this time must be added the burning-in time of two minutes and a 10% safety factor, so it would be necessary to use a resistor pad to slow down the feeding of the arc.

With a resistor pad a 9-mm positive carbon can be burned at 78 amperes and a 10-mm at 95 amperes to get one hour burning time. A pad would be necessary for each arc. While this would serve the purpose of securing the necessary length of time for the projection of the oversized reels, the use of the pad will further cut down the amperage at the arc and the light at the screen.

Projectionists should equip themselves with three pairs of glasses for use in viewing and focusing Natural Vision pictures. One pair will be identical with those worn by the audience, and used to watch the screen during projection of the picture. The other two pair are used to focus each of the two pictures on the screen.

One of these pair should contain two right eye lenses, this pair will cut out one of the pictures on the screen and allow focusing of the other. The other pair of glasses should contain two left eye lenses, so the other picture may be focused. These can be made by the projectionist, simply take two pairs of glasses, remove the four polaroid lenses, use the two right eye lense in one pair of glasses, then replace the two left eye lenses in the other frames. This was a trick used by projectionists, in projecting stereoscopic pictures in the late twenties.



Projector equipped with 5,000-foot reels and interlock selsyn motor—extreme right.

Paramount has prepared a booklet for managers and projectionists covering three dimension projection and these instructions should be strictly followed.

Owing to differences in design of soundheads, all projection rooms cannot advantageously use the same type of interlock. Either the mechanical or electrical interlock may be more practical, depending upon the type of soundhead installed. With most soundheads, the electrical interlock is preferred; these are the kind that have relatively high speed motors which are mounted in front of the soundhead and operate at speeds of from 3450 to 1750 revolutions per minute. If such motors were linked mechanically by any simple contrivance, a high-speed belt, chain or shaft would obstruct a critical location in the projection room.

Where the soundheads are Western Electric types 206 or 208, the electrical interlock is less practicable and the mechanical interlock more so, and a mechanical arrangement is preferred. In this equipment, a speed-reducing gear exists, interposed between drive motor and the projector. A mechanical interlock can be coupled to the low-speed (360 rpm) side of the drive. A shaft free to revolve, and having a sprocket wheel at either end, is mounted along the front wall of the projection room, under the ports; a sprocket chain from each projector drive runs forward to the two sprockets on the shaft. This equipment is very simple, is not in the way, and does not operate at a dangerous speed.

Assuming that the theatre is normally equipped and its apparatus is in good condition, the following materials are all that are needed to convert for Natural Vision three-dimensional projection:

Interlock, mechanical or electrical (1)
Metallized-surface perforated projection screen (1)
24-inch magazines (4)
23-inch projection reels (4)
Porthole frames for holding polaroid filters (2)
Polaroid filters (4)—two of these are spares
Test film, 100 feet long (1)
Staticmaster brush, for cleaning the filters (1)

Except for the screen, all of these can be purchased from Natural Vision. The screen used in the California showings was the Walker P. M. Polarized High Intensity, sold by National Theatre Supply Co. The Staticmaster brush is manufactured by Nuclear Products Co. of El Monte, Calif. A nuclear material—polonium—is built into its ferrule. The radiation from this metal slightly ionizes the air, neutralizing the static electricity that causes dust to cling to surfaces.

ELECTRICAL INTERLOCK INSTALLATION

The electrical interlock kit consists of the following:

Connecting cable (1)
General Electric selsyn motors (2)
Sprockets, to keep selsyn speed below 1200 rpm (4)
Lengths of sprocket chain (2)
Motor mounting plates (2)
Motor mounting bolts (12)

The two holding bolts at the left side of each drive motor are removed; two of the long bolts furnished are substituted—threaded up from the bottom on the regular motor bracket—and tightened; the motor mounting plate and sprockets installed on the selsyn fastened to them (after aligning) with washers and nuts.

Each selsyn motor is then loosely mounted on its mounting plate and sprockets instaled on the selsyn motor shaft and on the drive motor shaft (large sprocket on the selsyn). The silent-chain connection between selsyn sprocket and drive-motor sprocket is installed and adjusted, and the selsyn motor mounting bolts are then tightened down.

Selsyn motors are inter-connected by means of the electrical cable supplied.

Both projectors are turned by hand several times as necessary until each is in a position meeting these three requirements: (1) intermittent movement has just turned; (2) shutter is straight up and down, and

(3) Allen set screws on selsyn motor are straight.

With projector positions synchronized as above, the selsyns are energized by plugging in the AC plug of the electrical cable that connects them. The projectors will now remain synchronized. If the position of one is changed by hand, the selsyns will automatically make the same change in the position of the other; in operation, if either motor lags the selsyns will pull it ahead.

(When the theatre is closed down at night the selsyns are de-energized by unplugging the cable.)

PROJECTION ROOM CHANGES

Aside from installation of the interlock, whether mechanical or electrical, the following changes are necessary in all projection rooms:

The regular drive motors are wired to a common switch so they will start and stop together. If these motors are not switched simultaneously a serious strain would be thrown on the interlock system.

The 24" magazines are installed. If the projector pedestal interferes with the installation of the lower magazine, the latter must be offset for clearance. A wedge for this purpose must be made up in a local machine shop.

The twin images of the third-dimension screen image are displaced on the screen by exactly the proper distance only if projector alignment is perfect. To obtain this condition of alignment, short loops are made from the test film furnished, and projected simultaneously, projection light is reduced to a minimum to prevent warping of the film. The projectors are then realigned until the two sets of lines projected from the two test loops superimpose perfectly. If absolute perfection cannot be obtained it is at least necessary to make certain that lines from the left projector stay to the left of lines from the right projector. A reversal would produce serious eyestrain; any imperfection at all of alignment produces some eyestrain.

The porthole filters are installed. Each filter frame consists of an upper bar with rings, and a lower bar with clips. The location of the center of the light beam in the projection port is found, and the upper bar so mounted above the port that the polaroid filter will be centered on the light beam.

The upper bar must also be accurately level—for this reason a spirit level is supplied with the Natural Vision conversion "package." The lower bar need not be levelled. It is installed at a distance below the port that will provide easy clearance for removing the filter. (The filter is removed from the port for cleaning and also whenever a standard, non-stereo show is projected. Cleaning—of both sides of each filter—is done daily with Staticmaster brush.)

The filter marked "left" is installed over the left port facing the screen and the one marked "right" over the other; each filter also is marked on either side "toward lens" and "toward screen," and is installed accordingly. The spare filters also are so marked—this is why two spares are needed; they are not interchangeable.

The instructions add this warning: NEVER PROJECT WHITE LIGHT THROUGH THESE FILTERS. YOU WOULD RUIN THEM.

RUNNING THE SHOW

Following are the exact instructions given for running the picture Bwana Devil.

This show consists of four 23'' reels marked as follows: "Left First Section," "Left Second Section," "Right First Section," and "Right Second Section." Each section runs approximately 50 minutes.

Thread reel marked "Left First Section" in left machine facing screen. Thread reel marked "Right First Section" in right-hand machine facing screen. Be absolutely positive that start marks are threaded the same on both projectors as a difference of one frame between projectors is noticeable and results in eyestrain to the viewers.

Focusing before the show starts is done without wearing polaroid glasses. For proper focusing start both projectors, open left machine light and focus same. When sharp focus is obtained douse this light, open light on right machine and focus. Mark the position of each adjustment. Whenever regular pictures are to be shown remove the filter and re-focus. Mark this focus adjustment position also.

During Operation. The credit titles of Bwana Devil afford an excellent opportunity for checking horizontal lineup and focus.

To check horizontal lineup do not wear glasses. Both titles should be superimposed. If titles are not in proper alignment use framing handle on one projector only.

To check focus wear glasses. Cover left eye. Check focus on right machine. Then cover right eye and check focus on left machine.

Film Break. In the event of a break in the film, stop the projectors immediately and proceed as follows:

If your print has footage numbers, use a china marker to give you start frames on the same number on both projectors.

In the event your print has no footage numbers, pull down to first frame of next scene on both projectors. Use this first frame as start mark. Mark starting frames "Top" and "Bottom" to avoid any chance of misframe on starting.

When patching Bwana Devil film, if it becomes necessary to sacrifice a frame or frames, insert an equal number of frames of opaque leader so that the two reels will always remain matched, and run sound from the unpatched reel.

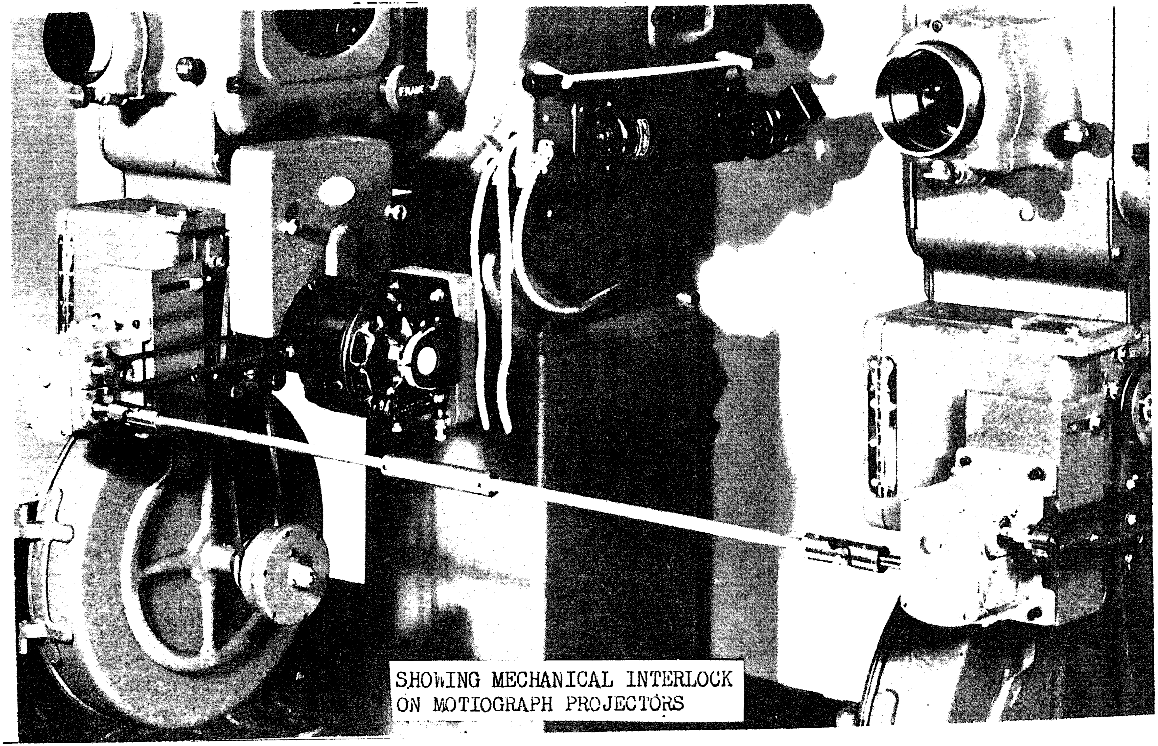
Because 23'' reels are used, it is necessary to raise the rewinder approximately three inches. This can be done by remounting it on a suitable block of wood or, preferably, by having an iron strap support bent to shape by any local iron worker.

MOTIOGRAPH MECHANICAL INTERLOCK

This equipment provides synchronous operation of two projectors for the presentation of third dimension pictures. It is designed for operation with the SH-7500 sound reproducers and projectors which are driven with the SH-7030 mechanism drive.

A minimum of seven inches clearance between the front of the soundhead and the front wall (at zero projection angle) is required to provide proper mounting of the gear boxes. With this condition (zero angle) the cross shaft is 31½ inches above the floor and 3 inches from the front wall. With a ten degree angle the shaft is 28 inches above the floor and 6 inches from the front wall. Any boxes or cabinets on the front wall must clear this shaft which revolves at a speed of approximately 50 RPM. If desired a sheet metal shield fastened to the front wall can be used to cover the cross shaft.

The gear boxes are shipped dry and should be filled to the check plug level with Texaco 650T cylinder oil, Shell Valvata oil J-83, or one of the other oils listed under Oil No. 8, in the Eberhardt Denver Company lubrication bulletin No· 23, which is packed with each gear box. The usual precautions should be taken to see that the projection room temperature is not too low when starting the machines.



SHOWING MECHANICAL INTERLOCK
ON MOTIOGRAPH PROJECTORS

The gear boxes should be mounted on the SH-2838 angle brackets using the A-300 Screws and A-540 washers. The brackets are then mounted on the soundheads using PS-1438 Screws and CS-1236 washers. The SH-2839 Gear Box mounts on the left (facing screen) on No. 1 soundhead, and the SH-2840 on the No. 2.

The universal joint on each shaft assembly is stamped to indicate which gear box shaft it is to be pinned to, the number one shaft assembly has a No. 1 stamped on the coupling and the shaft on the No. 1 gear box is also stamped· In all cases the number will appear adjacent to the larger diameter of the tapered hole.

If the difference between the projector lens centers is between 5' 8" nd 6' the standard size cross shafts will be ready for use. For shorter distance an equal amount should be removed from each shaft and the cross shaft sleeve tightened in place only after the gear boxes and bases are in their final positions, as it is very important that the cross shaft is not under tension or strain.

It will be necessary to saw or file off a portion of the SH-7032 guard assembly to provide clearance for the chain which drives the gear box. Removal of approximately one-half inch from the bottom of the casting should be sufficient.

TO PROVIDE SYNC THROUGH INTERLOCK

To provide a convenient means of adjusting and checking for synchronous operation as well as a threading aid to prevent loss of synchronism when threading the mechanics, a number of sync indicator decals are supplied.

Each machine is turned in normal direction by hand, until the intermittent sprocket moves down exactly two teeth (the intermittent has completed one-half of its travel for pulling down one frame of film) and a sync indicator label is applied to the upper sprocket with a pair of the dark wedges in the vertical position. These wedges in the vertical position will then indicate the unlocked position of the intermitten movement and when the numbered sectors are in the vertical position, the intermittent will be in the locked or threading position.

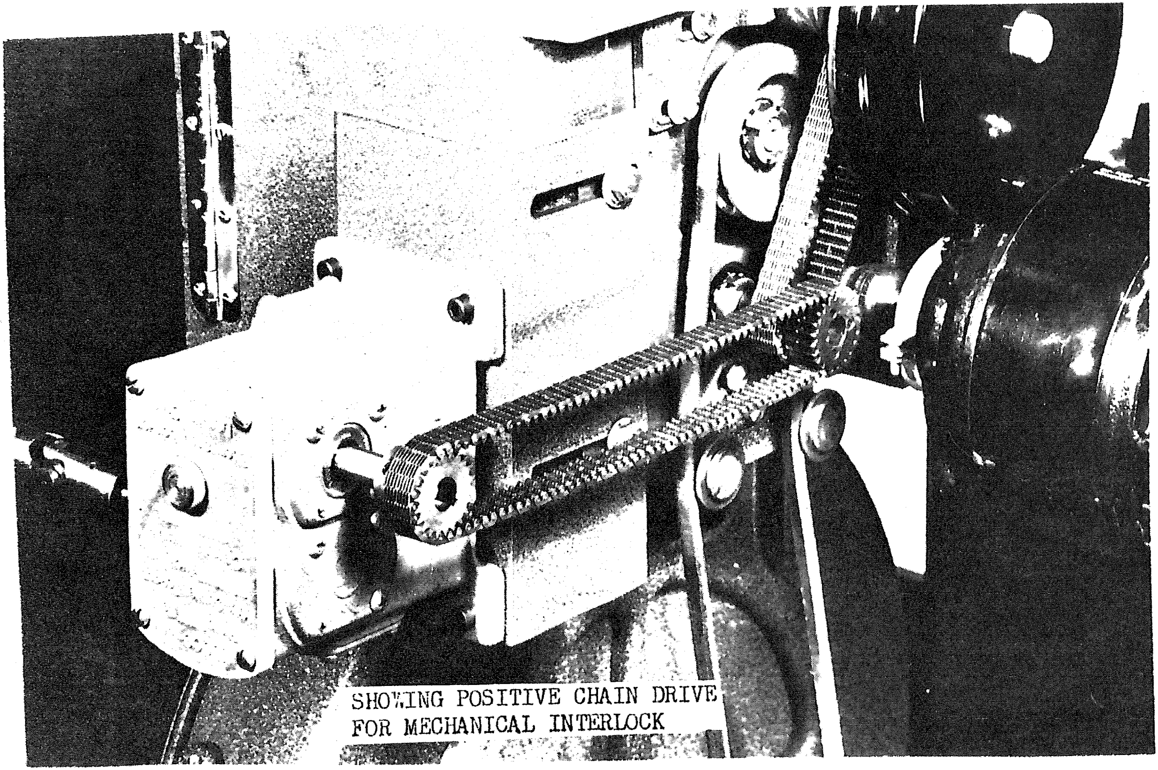
Replace the regular SH-2532 sprockets with the SH-2837 double sprockets, being careful to see that the SH-2667 woodruff key remains in the shaft.

Install chain on No· 1 soundhead and gear box and adjust bracket until chain is tight. (It may also be necessary to readjust the SH-7015 drive chain assembly as all chains should be tight.) Turn down No. 1 machine until the No. 1 sector on the sync indicator is centered in the vertical position and at the top of the sprocket.

Turn down No. 2 machine until the No. 1 sector is in the same relative position as on No. 1 machine. Turn chain sprocket on No· 2 (left) gear box in counter-clockwise direction until it just becomes tight, taking up any end play in gear box. Install No. 2 chain and adjust to proper tension (tight) without changing position of either sprocket.

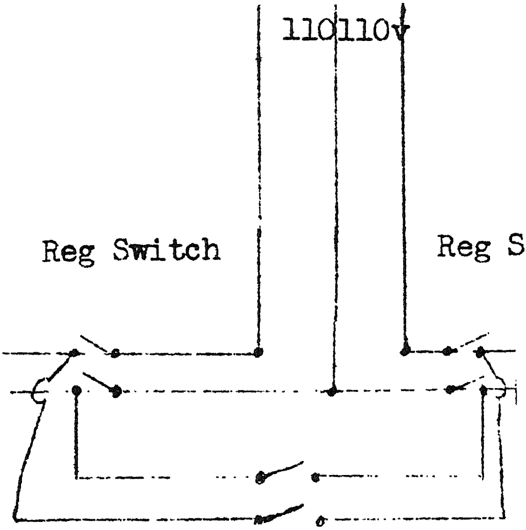
As different projectors have various amounts of overall backlash in the gear systems, it may be necessary to compensate for this condition with a different setting of the chain sprocket, on gear box before putting on the chain.

Instead of turning the sprocket counter-clockwise until it becomes tight, it may be necessary to turn it in the clockwise direction by various amounts until a test run indicates that the sync indicators stop on the same numbered sectors. If the sectors stop one number apart,



SHOWING POSITIVE CHAIN DRIVE FOR MECHANICAL INTERLOCK it indicates that the condition can be corrected by a different setting of the chain sprocket. Once this setting is found it should always result in proper synchronism each time it is set up.

Use straight edges to align chain sprockets and double check the cross shaft sleeve to see that the shaft is not under tension or strain. Tighten all set screws. The two machines are now mechanically interlocked and extreme caution must be observed to see that both motors are energized at the same time with a common switch· Perhaps the easiest way (other ways will be evident in different projection rooms) is to parallel the two motors with a DPST switch in the circuit, as shown in the diagram.



With this additional switch closed both motors would be operated from the No. 1 switch. When opened each motor would operate from its regular switch. The fuse or circuit breaker capacity would have to be changed to take care of the dual operation. Extreme caution must be used by the projectionist to avoid electrical or mechanical trouble due to operation of switches.

OPERATION OF INTERLOCK

If the above instructions are followed it should be possible to start and stop the machines, by means of the common switch, several times with the sync indicators stopping together each time.

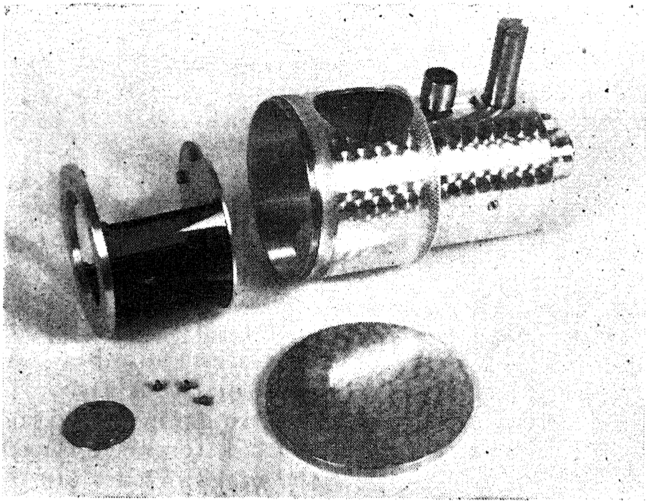
In case a dark wedge should stop in the vertical in case a dark wedge should stop in the vertical position on one machine, it is only necessary to turn the machine by hand to match the numbered sector on the upper sprocket of the other machine before threading.

A test loop (two identical loops are required) for each machine can be made by using numbered leader stock and running through the machine as continuous loops. The numbers from each projector should flash on the screen at the same instant. A difference of one frame is difficult to detect and if the machines are out of sync two or more frames the time lag is very evident. It is important that the machines never be out of sync more than one frame.

MAINTENANCE. The sprocket chains should be operated with very little, if any, slack. Apply a little projector oil daily to the chains and universal joints. Maintain proper oil level in gear boxes. Too much lubricant may cause them to overheat. After 500 hours of operation the gear boxes should be drained, cleaned with kerosene and refilled with new oil.

When changing from 3-D to conventional projection, loosen screws holding gear box brackets and remove chains. For the next 3-D showing it will be necessary to repeat the synchronizing operation.

All other third dimension systems using glasses for viewing the projected pictures are similar to Natural Vision, so it would only be a duplication of effort to list these individually.



-Direct drive polarizer attachment, showing barrel and mounted polaroid filter. The filter rotates before projector lens, is heart of the alternate frame technique described by author.

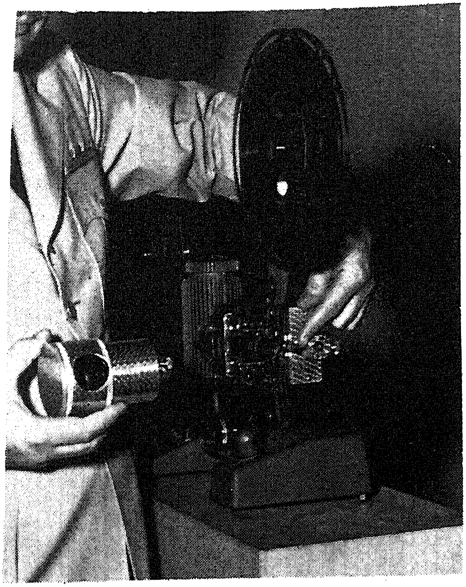
ALTERNATE FRAME SYSTEM

A system of third dimension motion pictures in color for use with a Bell & Howell 16 mm projector, has recently been developed by the Technical Photographic Service Section, of the Wright Air Development Center, in Dayton, Ohio.

Major Robert V. Bernier who helped in developing the equipment explains its adaptability and applications

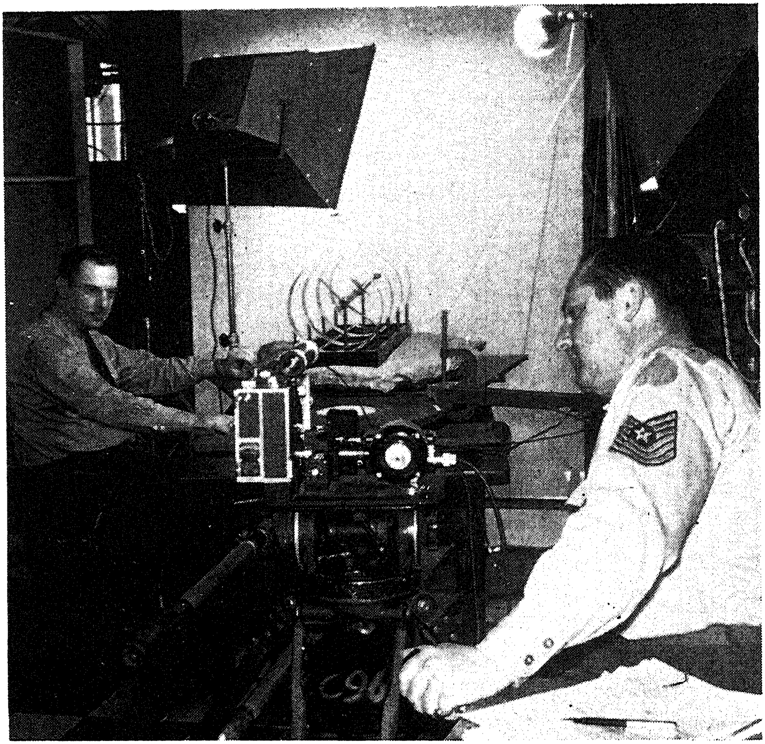
To be sure, there are applications of the three-dimensional motion picture other than for entertainment purposes. These are principally in the fields of education, industry and science. Here, portability of equipment and low production cost are prerequisites to the use of such films. For this reason, 16mm film seems to be the choice medium for motion pictures of this type.

The original decision to concentrate effort on improvements to the alternate frame technique was based on the possible advantages which could be had by maintaining full frame standards and at the same time confine at least the projection to a single standard film. Fig. 6 shows a sample strip of alternate frame stereo movie film. On projection the right eye will see every alternate frame, the left eye will see those in between.



Note the difference in position of objects on adjacent frames with respect to each other and to the edge of the film.

The projection requirements for alternate frame film are substantially the same as they are for stereo film of other systems. The right and left eye images must be registered properly on the screen and must be selectively polarized for their respective eyes. With this system it has been the practice



–Major Bernier aided by Master Sgt. John C. Blotner, Jr., prepare to shoot a scene for a three-dimensional color motion picture, using a Cine Special camera.

to use the same type of attachment on the projector that was used on the camera. Such an attachment, a beam splitter with synchronized shutter, was tested prior to the development of the present adapter. The latter was developed in an attempt to eliminate the screen registration problems characteristic of the beam splitter attachment.

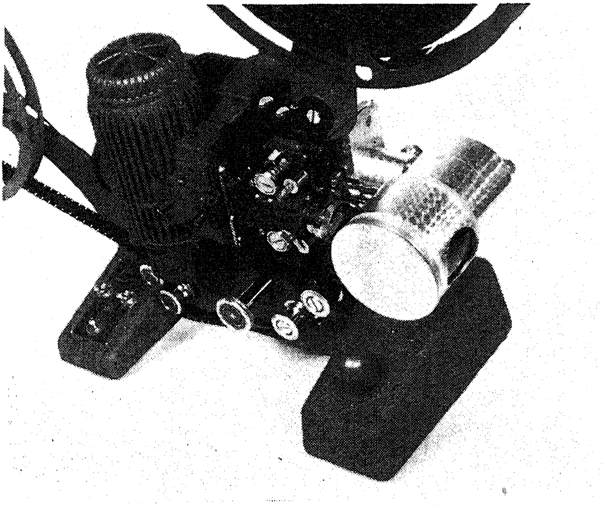


FIG. 4—Polarizer attached to a Bell & Howell 16mm projector which is specially equipped with a Morgana film movement. This solved the excessive flicker problem. Polarizer is gear-driven by projector.

Fig. 7 and 8 show the principle of it's operation. Refering to the diagrams, the polaroid filter 16 is semicylindrical and positioned to be rotated on its axis, which is in the same plane as but normal to the lens axis. Polarization of the filter (20) when viewed from the lens position is 45 degrees upward and to the left. The film frame (22) having a left stereoscopic image therein is centered on the lens axis. The image (24) on the screen (18) may be seen with the left eye only by a viewer wearing standard Polaroid spectacles. In Fig. 8 the film (12) has been advanced so that a frame (26) having a right stereoscopic image thereon is centered on the lens axis while the filter (16) has been revolved one hundred eighty degrees from the position it occupied in Fig. 7. It is noted that, in Fig. 7, the outside of the semicylindrical filter (16) is presented to the lens (14) while in Fig. 8 the inside of the semicylindrical filter is presented to the lens (14). Moreover, the same axis (20) of polarization which, in Fig. 7, extended upwardly and to the left, now extends upwardly and to the right. Thus the image (28) on the screen (18) may be seen with the right eye only by a viewer wearing standard Polaroid spectacles.

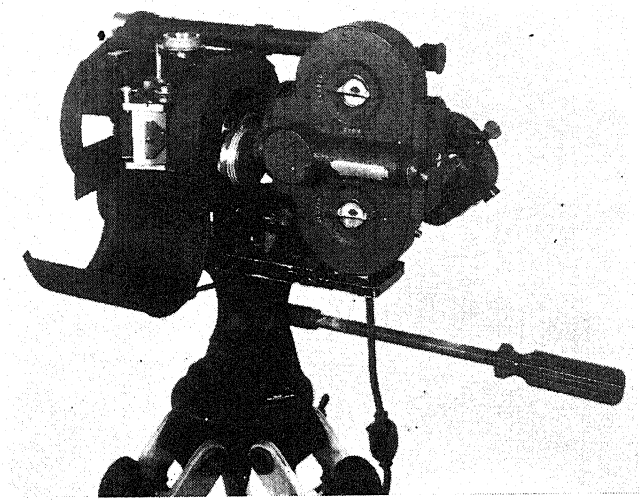


FIG. 5—Bell & Howell 16mm Filmo camera with stereo alternate frame selector. The camera mechanism is coupled with the gear train which drives a 180 degree shutter in front of the beam splitter.

Three stages of evolution of the barrel type polarizer attachment were first, a barrel driven through a gear train by power transmitted by the film itself; second, the same attachment geared to operate at three times its original speed so that it could be used on a projector incorporating the Morgana shuttle movement, and third, an entirely new gear housing driving the same type of barrel polarizer through a direct power shaft on the projector.

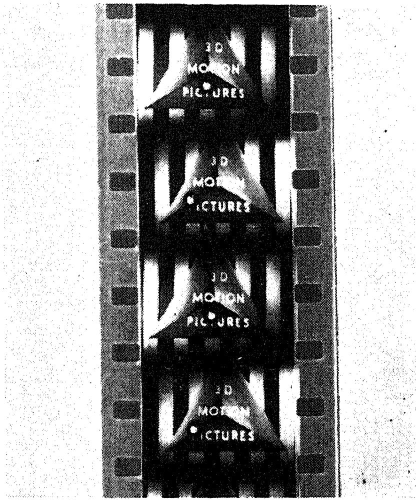


FIG. 6—Clip of 16mm alternate frame stereo film exposed on double perforated Fastax film. Note difference in position of objects in R and L frames.

In the first stage described above, the film is threaded through a sprocket drive on the attachment. The latter has no other power connections to the projector. This attachment was first designed so that it could be used on most any 16mm projector. The movement of the film through the sprocket drive was sufficient to keep the polarizer in synchronization with its movement through the film gate. An adjustment knob on the attachment provided for changing the position of the drive sprocket with respect to the power sprocket on the projector. The increase or decrease in distance, by one frame length, between the two sprockets served to synchronize the rotating polarizer with right or left frames, at will, during projection. This was necessary to compensate for discrepencies in the right, left, right, etc., sequence in the film due to threading or splicing errors.

As predicted the flicker at 24 frames per second was considerable. Increasing the speed of projection to 36 frames per

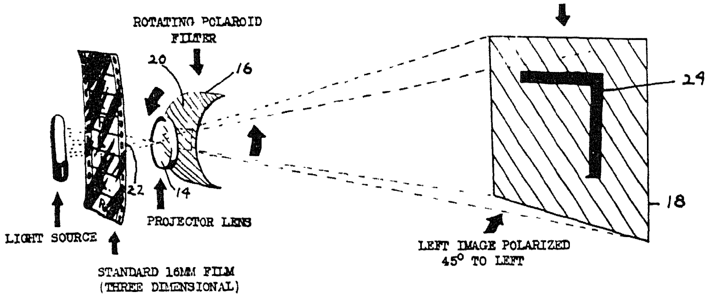


FIG. 7—Diagram above and below illustrate principle of alternately and selectively polarizing right and left screen images. Here rotating filter is in place for left image registration.

helped somewhat but it was soon realized that some other approach to the problem would be necessary. The Morgana shuttle movement proved to be the solution to the flicker problem. This unique movement was designed to eliminate the some sort of flicker in the two-color process. A search uncovered the existence of one of these mechanisms at the Bell & Howell plant in

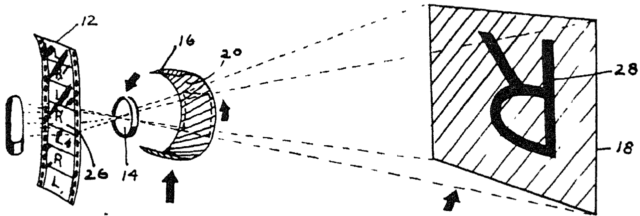
Chicago. It was procured and mounted on a Bell & Howell Show-Master projector.

The first film-driven polarizer attachment was regeared to revolve at three times its former speed so as to correspond to the new framing speed of the Morgana movement. Previously while one eye was getting the benefit of three "flicks" the other had to wait through a period of 1/24 second. Now with the Morgana movement the fluxation of light, with respect to either eye, was uniform. The system which involves shuttling one frame backwards for every two forward, facilitates progression of the film through the projector at standard sound speed, and at the same time provides a flicker frequency of 72 frames per second, or 36 frames per second per eye.

The polarizer in this case is powered through its gear train direct by the gear mechanism of the projector, and not by the film. This change was found to be necessary due to the lack of the film-driven model to stay in exact synchronization at the higher speed required with the Morgana movement.

The alternate frame principle offers certain advantages over the split image system. Both the right eye image as well as the left eye image, each occupy a standard full frame on the film. This feature provides for maintaining the quality standard for 16mm projection. The alternate frame principle also facilitates projection through single undisplaced axis from the projector aperture straight to the screen. Because of this feature there exists no requirement to manually register the two images on the screen.

Registration, on the other hand is accomplished during the filming or during processing and is accurately maintained in the film gate aperture of the projector and likewise on the screen. Effects which should result from calculated lateral image displacement are faithfully reproduced on the screen. In contrast the usual type of beam splitter displaces the axis of, and re-registers the stereo images separately. As a result the effects intended at the time of the photography are seldom accurately reproduced on the screen. In addition, and because of projectionist errors, vibrations, etc., the beam splitter system can be cause of misregistration which in turn results in eyestrain. Unfortunately many believe, unjustly, that such eyestrain is characteristic of any and all three-dimensional pictures.



FILTER AFTER HAVING
REVOLVED 180°
FOR NEW FRAME

IMAGE POLARIZED 45°
TO THE RIGHT

FIG. 8—Rotary polarizing filter in place for projecting a right hand frame image. Fig. 6, above shows respective frames.

Although the Morgana movement accomplished wonders in solving the flicker problem it introduced a limitation in the allowable rate of action of moving objects. Any fast subject movement, especially laterally, appears considerably jumpy on the screen. The reverse shuttling feature of the Morgana movement, of course, is directly responsible. To be sure this new bug is troublesome, but it is not nearly as detrimental as was the flicker condition. (Patents are now being procured on an improvement which will eliminate this last remaining bug.)

Four different cameras have been adapted for alternate frame stereo motion picture photography. With this equipment a wide variety of applications have been possible. It should be noted that the mission of the Stereo Sub Unit, WADC Photographic Service Section, Wright-Patterson Air Force Base, is to accomplish any type of stereo photography which it might be called upon to perform.

Sixteen-millimeter cameras which have been adapted for alternate frame stereo photography are: Bell & Howell Filmo, the Eastman High Speed, an Eastman High Speed with Graham transmission, and a Cine Special. Each of the modified cameras listed now accomplish the requirement of exposing the right and left stereoscopic images on alternate full frames of the film.

Cameras equipped with barrel type shutters lend themselves conveniently to alternate frame stereo adaption. In such cases the barrel type polarizer principle can be in corporated as an integral part of the shutter. A split polaroid filter on the lens of the camera then provides for alternate selection of the right and left views on each 180 degrees rotation of the shutter. The axis of polarization of either half of the split filter on the lens is 45 degrees to the vertical and opposed by 90 degrees. Since the axis of polarization of the filter in the shutter is also on a 45 degree diagonal it acts, together with the split filter on the lens, to alternately eclipse either half of the latter during each half revolution. Thus, when a beam splitter is centered in front of the lens, the displaced right and left views therefrom, entering their respective halves of the lens, are recorded selectively on alternate frames of the film. This method of selection is particularly advantageous in high speed work where, otherwise, a mechanical shutter selector would be impractical.

Both of the modified Eastman High Speed Cameras mentioned are equipped with a polaroid filter mounted in the barrel shutter compensator.

The compensator was specially constructed by Eastman Kodak Co. It contains a sheet of polaroid mounted between two optical glass plates. The refracting action of this optical assembly corresponds to the specifications of the standard Eastman high speed compensator. Since there are no additional moving parts involved in the high speed stereo adaption, the camera can be operated at its maximum speed. There is on disadvantage in this system however, in that light equivalent to two lens-stops are lost through the polaroid filters.

Because of the simplicity of the optical selection of right and left images provided by the barrel shutter, one of the Eastman high speed cameras was modified to provide constant film speeds over a range from 1 to 176 frames per second. This was accomplished by powering the camera with a Graham transmission.

The beam splitter used in the attachment on the Bell & Howell camera provides a choice of either a 2½'' interocular or a 6'' interocular. The latter is used with either the four or six inch lens to maintain normal depth proportions. This six inch beam splitter is equipped with a parallax-free view-finder which incorporates a half-silvered beam displacer. This feature provides a method of accurately registering the right and left beam splitter images with respect to the central viewfinder image. The actual registration of the separate images is accomplished by rotating the outer mirrors of the beam splitter. The rotation of the mirrors in effect converges or diverges the two viewpoints of the system in accordance to the effect desired when the film is screened.

At normal and slower speeds mechanical shutters can be operated and synchronized by the camera or other means.

There are several other systems employed in the making and projecting of stereoscopic motion pictures, The Parallax Stereograms, Lippman's "Intergral" System, The system used by William Friese-Greene in 1893, in which he employed two negative films, one behind each lens. The various "grid" systems in which a screen made up of a number of parallel opaque bars are employed. The process employed by Jean Zafiropulo which uses a film containing embossed spherical lens elements in its base.

None of these systems however is now contemplated for use, so will have no immediate interest for the reader.

STEREOPHONIC REPRODUCTION

FANTASOUND SYSTEM

The RCA Fantasound system is really three complete sound systems of a special type combined into one. In presenting the picture two films are run simultaneously, one a standard film with picture and soundtrack, and the other a special 35 mm. sound film with four double-width soundtracks. Three of the soundtracks are standard program tracks carrying music and dialogue, while the fourth is a special control track that will be described in detail subsequently.

The sound film is run through a special multi-track soundhead, which is synchronized with the associated picture projector by means of a Selsyn drive. Provisions have been made to run the two special soundheads in conjunction with any two of the three available picture projectors.

The signal outputs of the four soundtracks pass through a special relay fader system and are amplified by four separate pre-amplifiers. Each of the three amplifiers handling program material feeds a special variable gain amplifier, which in turn feeds a 30-watt driver amplifier. Each drive amplifier feeds two 60-watt power amplifiers connected in parallel, giving a rated output of 120 watts per channel. While these amplifiers are rated at 120 watts, it was found in tests that they actually delivered 200 watts with less than 2% distortion. This makes a total of 600 watts of undistorted power output available for the three main channels.

To handle this tremendous power output three huge de luxe loudspeaker systems are located on the left center, and right side of the stage. Each setup has 4 large folded type low-frequency baffles with 8 low-frequency speaker units, and one large cellular high-frequency horn with special throat and 4 high-frequency speaker units. This gives a total of 36 de luxe speaker units on the stage!

Two additional 50-watt power amplifiers are connected to the driver amplifier on the two side channels through suitable attenuator pads. Each of these amplifiers drives 22 small cabinet-type loudspeakers that are distributed about the auditorium.

The fourth, or control, track recording on the sound film automatically controls the gain of the three variable gain amplifiers in the three main amplifier channels and hence automatically controls the loudness of the reproduction from each of the speaker set-ups. The control track is a recording of three different artificial oscillator tones of varying intensities superimposed on one another. The three tones are amplified by the control track pre-amplifier, then further by the amplifiers in the control track, and finally passed into filters which separate the tones from one another and feed each to the proper variable-gain amplifier.

The gain, or "volume-control setting," of the variable-gain amplifier is determined by the strength of the control tone that reaches it. Hence, by increasing the intensity of one control tone with respect to the others on the soundtrack it is possible to make the gain of one amplifier channel greater than the others and the reproduction from one set of speakers louder than the others.

With this brief description of the function of the Fantasound system let us see how it is possible to get more realistic reproduction than can be obtained with a standard system.

A recording of a symphony orchestra reproduced by a standard system does not have all of the tone color and spirit of the original because the volume or dynamic range has to be *compressed* when the recording is made. Physical limitations of the recording system make compression necessary. The smallest modulation that it is practical to record on a soundtrack is limited by the film background noise. The limit is reached when the ratio of signal to noise becomes so small that noise becomes perceptible in reproduction.

The largest modulation that can be recorded is 100% when the peaks of the recorded wave extend to the very edges of the soundtrack area. The dynamic or volume range between these two limits is approximately 35 decibels; whereas the actual range of a symphony orchestra is approximately 70 decibels. Thus a means must be provided for restoring the 35 decibels that were lost because it was necessary to compress the range in the recording process.

If it were possible for the projectionist to twirl the volume control knob rapidly enough according to a complete set of cues, he could continually boost or reduce the gain by just the right amount at the right time and thus compensate for the compression introduced during recording. However, because of the innumerable changes required, this is too tough an assignment, hence some sort of automatic means must be used. In the Fantasound system this means is the control track and the variable-gain amplifiers which are inserted in each amplifier channel.

The control track was recorded after the final rerecordings of the program tracks were made in approximately the following manner. The output of an oscillator generating a single artificial tone, let us say 250 cycles, was connected both to the input of the control track recorder and to a variable-gain amplifier in a standard reproducing system. As each recording was played through the reproducing system, a musician controlled the output of the oscillator in accordance with a set of cues that had been carefully worked out. As he varied the level of the oscillator signal to the variable gain amplifier, he restored the full dynamic range of the original music to the reproduction. At the same time all of the minute variations in the level of the control tone were being permanently recorded on the control track to be used from then on to automatically control the volume in reproduction.

A control track was recorded in the aforementioned way for each of the three program tracks, but a different frequency control tone was used for each. The three resulting control records were then combined into one and recorded on the sound film along with the three program tracks.

The extra volume range obtained by this method is about 40 decibels or about 10,000 times that of a conventional system. This extra amplification would not be of much value if the power amplifiers and loudspeakers were not capable of handling the tremendous peak powers this amplification requires. As described in the foregoing text, a total of 700 watts of audio power with neglible distortion and 80 loudspeaker units were provided to handle these peaks!

Having the loudness of the reproduction as great as that of the original is in itself not enough to give a feeling of realism. In fact, it has been proved that when music is reproduced over a single channel, the audience becomes uneasy if the music is made very much louder than normal. This has been found to be due to the fact that theater loudspeakers are necessarily very directional and, therefore, all the sound appears to come from a single point. This does not mean that directional characteristics of theater loudspeakers are necessarily undesirable. On the contrary, this characteristic adds greatly to the illusion on dialogue, and helps to obtain acceptable intelligibility under adverse acoustic conditions.

An orchestra, however, is generally spread out over all of the stage. Many of the sound waves they create are non-directional. It is not surprising, therefore, that the reproduction of such an orchestra over a single channel system with highly directional speakers leaves something lacking.

In the Fantasound system three huge main speaker systems occupy a width greater than that of the sound screen, so that the sound comes from the whole stage and not just one section. In addition to the stage speakers, small cabinet-type speakers are installed along both sides of the auditorium and across the rear. Normally, these are operating at so low a level that the audience does not realize they are there; however, they add materially to the illusion.

When directional stage speakers are used even though they are spread, most of the sound energy is directed down into the audience, and much less sound energy strikes the walls than if a live orchestra were playing. If a person were seated in an auditorium listening to a live orchestra, much of the sound reaching his ear would have been reflected from the walls about him so he gets the illusion of sound coming from all sides. The additional auditorium speakers help simulate this condition in the reproduction of Fantasia and places the audience in the midst of the music.

One further effect which adds realism to the sound reproduction is that of "acoustic perspective", or the process of making sound move about the screen in accordance with the action taking place. This can easily be accomplished with the Fantasound system, since three separate channels are available each with its own signal source and loudspeaker system. Disney uses acoustic perspective to obtain very striking effects in this picture.

The tremendous amount of research and study involved in developing this unique sound system and the experience gained in its installation and test have opened up a complete new field in sound-on-film reproduction. It is felt that many of the advantages of this system can soon be made available to all theaters in a somewhat simplified form.

It is noteworthy that, aside from the special multi-track soundheads and variable gain amplifiers, all components of this special sound system are standard sound reproducing items that are being sold with current theater sound equipment. This means that if the application of these special recording methods becomes more general, the sound equipments now installed in theaters will not become obsolete but instead may be used as the main part of a new enlarged system.

Because Disney wanted to produce unusual effects with acoustic perspective, making the sound appear to move about the auditorium and issue from many sources instead of only one as in a standard sound reproducing system, it was necessary to expand the Fantasound system into three complete sound systems, with three separate amplifier channels and three stage speaker setups located on the right, center and left of the stage, respectively.

To supply each of these three channels with separate sound sources, it was necessary to use three program soundtracks instead of the usual one. Then to automatically adjust the volume level of each channel to get greater volume range and more realistic reproduction, it was necessary to use a fourth track, which is known as the control track.

Obviously, there was not room on a standard film for four soundtracks, so a special sound film carrying the three program tracks and the control track was recorded on standard 35 mm. stock. In reproduction, the sound film and the picture film are run simultaneously, the former in a special multi-track soundhead and the latter in a standard picture projector.

The control track has three separate tones recorded on it, superimposed on one another. The tones used are 250, 630 and 1600 cycles. As will be shown later, the intensity of each of these tones determines the loudness of the reproduction from one of the three amplifier channels. Each of the soundtracks on this film is twice normal width, so that it is possible to record signals on them that are twice as loud as the loudest signal that could be recorded on a standard soundtrack.

The accepted volume range of a standard variable area soundtrack is 35 decibels. This means that if the weakest signal recorded on the sound track is made 35 decibels lower in level than the loudest signal that can be recorded within the limits of the soundtrack, the inherent film noise due to graininess, scratches, etc., becomes noticeable in comparison to the weakest signal.

By doubling the width of the soundtrack the loudest signal may be made 6 decibels louder, so that the total usable range then becomes 41 decibels with the same signal-to-noise ratio that is found in standard recordings.

Disney however, has chosen to limit the range that he actually recorded on the film to only 25 decibels, so that the weakest signal recorded on the "Fantasia" soundtracks is a full 16 decibels higher in level than the weakest signals found on standard soundtracks. This means that the signal at all times is many times greater than the film background noise and hence the reproduction is unusually quiet. It was possible to restrict the recorded range in this manner because the control track was available to supply the necessary volume range to the music once again.

The range of control on the variable gain amplifiers is so great that it is possible to expand the 25 decibel volume range recorded on the film to the full 70 decibel volume range of a large symphony orchestra.

To reproduce signals from four soundtracks simultaneously, RCA engineers had to develop a special multitrack soundhead. This soundhead has its own mounting pedestal and a set of upper and lower magazines. It is driven by a three-phase Selsyn drive motor which keeps it always in exact synchronism with the picture projector which is also driven by a Selsyn drive motor from the same Selsyn generator.

A double, reversible exciter lamp socket is provided carrying one active and one spare exciter lamp. If an exciter lamp should burn out, it is necessary only to remove the socket, reverse it, and re-insert it to put a new lamp in position. A special optical system forms the light from a signal exciter lamp into a uniform scanning beam that is one mil. wide and long enough to scan all four tracks.

A standard rotary stabilizer could not be used because the entire film has to be scanned and the solid sound take-off drum would not allow light to pass through. Hence a special aperture was developed to permit this type of scanning. A magnetically-driven drum located immediately below the aperture drives the film past the scanning point at a very uniform speed. The magnetic drive is identical to the one that has been used on all RCA Film Recorders for many years.

The meter shown in illustration indicates the strength of the current that is being fed to the magnetizing coils on the magnetic drive. The knob immediately below the meter adjusts a rheostat which controls this magnetizing current.

A pair of rollers ahead of the scanning aperture and another after the magnetically-driven drum maintain film loops which filter out any irregularities which may be imparted to the motion of the film by the feed and hold-back sprockets.

After the scanning light passes through the film at the aperture, it passes on to four photocells mounted in a front photo-cell compartment. Each photocell is connected to its own photocell transformer which matches the high impedance of the cell to a low-impedance line which couples the soundhead to the amplifier system.

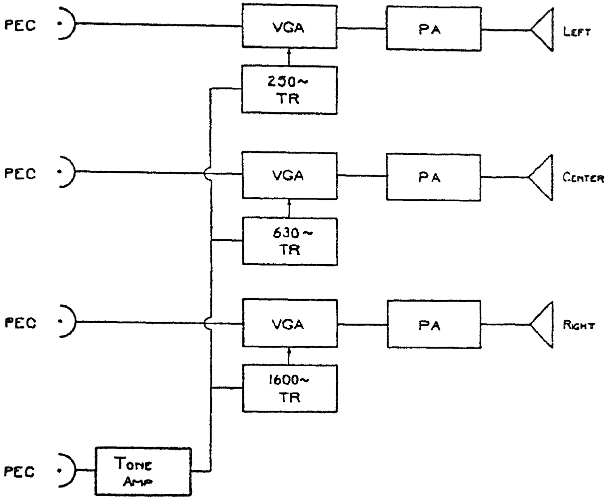
The complex control signal (combination of three tones) generated in the control track photocell is amplified and built up to a high level by a pre-amplifier, voltage amplifier, and a power amplifier. This high-level signal is then fed to each of the three main channel amplifier racks. A 250-cycle band-pass filter on Rack 1 accepts the 250-cycle portion of the complex control tone and rejects the other two tones. A 630-cycle band-pass filter on Rack 2 and a 1600-cycle band-pass filter on Rack 3 accept 630 and 1600 cycles, respectively, rejecting the undesired components. In this way, the complex control tone is separated into its individual parts and one tone goes to each rack.

After coming through the band-pass filter each control tone is fed to a tone rectifier which rectifies the A.C. tone producing a D.C. voltage. The value of this D.C. voltage is at all times proportional to the strength of the control tone, becoming higher as the control tone gets stronger.

The variable D.C. voltage is then applied to the grid circuit of the first amplifier stage of the variable gain amplifier as a bias voltage. The first stage of the amplifier consists of a balanced pair of RCA 6K7 tubes in a push-pull circuit. The RCA 6K7 is a remote cut-off, super control pentode tube so constructed that the gain of the tube may be varied over wide limits by changing the bias voltage.

Two ordinary amplifier stages follow this variable gain stage to further amplify the signal before passing it on to the power amplifiers. Controls are available on this amplifier to change the expansion characteristics so that varying degrees of volume changes can be obtained for a given change in control signal. By this arrangement the equipment can be adjusted to give any overall volume range that the size and acoustics of the theater will permit.

By the proper combination of these two new pieces of sound reproducing equipment with standard Photophone amplifiers, speakers, and power supply units, a very versatile system has been created which now brings unprecedented sound reproduction to theater audiences. It is expected that the future will bring even more unusual effects and more realistic reproduction.



Simplified block diagram of the Fantasound reproducing equipment.

WARNER'S "VITASOUND"

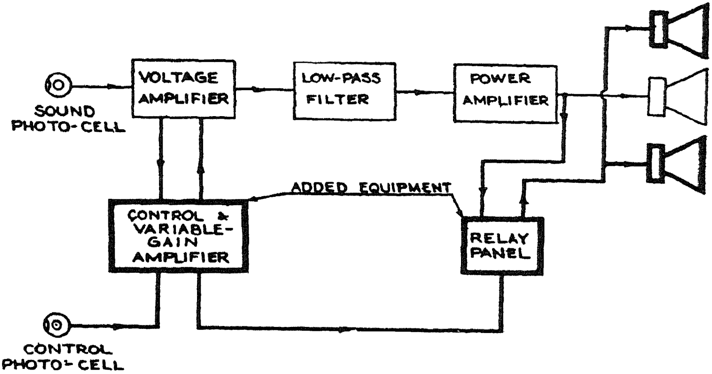
Vitasound employs a control track, but only one sound track, and they are on the same film with the image. Others under consideration similarly have both sound control and sound pickup from the picture print, but use two sound tracks. These latter, as we shall see in a moment, provide "stereophonic" sound. Like these, "Vitasound" has horn systems, one at either side of center speakers, but in Warner method all speakers of course get their signals from a single track, whereas in the two-track systems, the recording on one track may be associated with one side of the image, that of the other track with the opposite side.

"Vitasound" is the simplest of the group. It uses only two amplifying channels, although with three speaker systems. In a theater which at present has regular and emergency full-power amplifiers and three sets of speakers backstage, conversion to Vitasound operation would be comparatively simple. The existing soundheads would be modified for Vitasound reproduction (they would retain their capacity to play ordinary tracks in the ordinary way). The existing amplifier channels would be modified for variable gain operation, which would not involve sacrifice of their ability to function in the usual manner; and a control panel for handling the variable-gain control currents would be installed. That, and some changes in wiring to the amplifiers and the speakers, is all that would be required.

In the case of existing systems having but one full-power channel, and less than three complete sets of speakers backstage, it would be necessary to add a second channel, and a suitable number of additional speakers.

Vitasound is recorded on an ordinary track, exactly like any other sound. Additionally, however, the film carries a second track for control purposes, which is placed in the line of the sprocket holes, and carries a simple controlling signal for actuation of the variable-gain features of the amplifiers.

The special track works in this way: When the area between the sprocket holes is entire opaque, the special second photocell is illuminated only when a sprocket hole passes through the special exciting light. Since there are four sprocket holes per frame, and 24 frames per second, a 96-cycle signal results. This signal is of maximum intensity when the area between the sprocket holes is entirely opaque. When the signal track permits some transparency between sprocket holes, the 96-cycle intensity is reduced, and when the region between the sprocket holes is entirely clear, the signal strength is brought to its minimum.

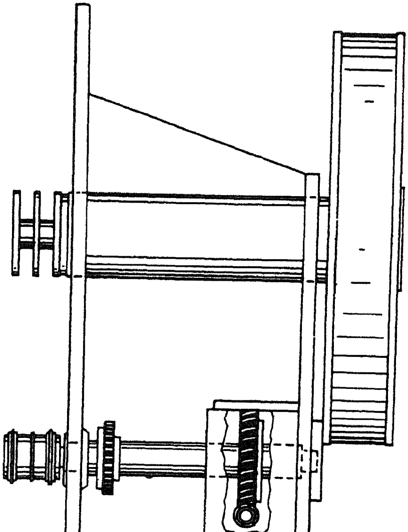


Block diagram of control-track apparatus.

This signal, amplified and converted to d. c., is applied equally to *both* variable-gain amplifiers, but the variable-gain circuits in those amplifiers are adjusted differently and do not respond in the same way to the same control signal. One amplifier supplies the central bank of speakers, the other both of the side banks (there are, as said, only two amplifiers for three banks of speakers). The difference in the setting of their variable-gain circuits is so arranged that when the control signal is at minimum the central speakers play normally and the side speakers do not play at all.

As the control signal strength increases the side speakers begin to function, and at about medium strength of the control signal, they are playing at the same volume as the central speakers. Further increase in control signal strength (still more opacity between sprocket holes) adds simplification to both sets of amplifiers, which are then producing louder sound than they would normally give for the same soundtrack. At a maximum control signal (complete opacity between sprocket holes) the automatic volume control of both amplifiers has been pushed up as far as it will go and the system is at maximum volume.

Being of what may be called a "tri-sonic" type, this system cannot produce a stereophonic effect. It incorporates the advantages of increased volume range, freed from previous limitations of on-film recording. It spreads the source of sound across the whole proscenium opening, or narrows it to the center of the screen, as required, all by means of automatic control. An illusion



Skeleton side view of film-propelling mechanism.

of true orchestral placement of instruments is produced, not as completely as with more elaborate arrangements, but nevertheless an illusion strong enough to be strikingly and to music lovers most pleasantly noticeable.

The sound acquires a very marked increase in depth and "presence." The side speakers can be used to produce a background of off-screen sound, and to some extent to tie in the audible source of sound with the pictorial source in the action on the screen.

TWO TRACK "STEREOPHONIC"

An intermediate system incorporating some of the advantages of both those previously described, has been identified as "stereo-control" sound. This arrangement also carries a special control track on the ordinary film. In addition, its splits the ordinary sound track, which occupies the usual area, into two narrower tracks, playing into a dual photocell. (The control track, in the sprocket hole region has its own photocell.) This arrangement also calls for modification of existing soundheads, not for special heads separate from the projector assembly.

The signal control track, placed between sprocket holes, differs from that previously described. It does not utilize the 96-cycle modulation produced by the sprocket holes themselves, but consists of three control frequencies of variable density recording photographed on the areas between sprocket holes. The 96-cycle sprocket-hole modulation is understood to be electrically separated from these control frequencies by filter networks, but the full details of this portion of the system are not as yet available. The two soundtracks, each half of the normal width, are placed side by side; each carries its own signal group.

One of these tracks is amplified by the single channel which supplies the central bank of speakers, the output from the other is equally divided between two additional channels which supply the right and left speaker banks. Each of the three channels includes a variable-gain amplifier, the amplification being controlled by one of three control frequencies on the special track.

The results from this system approach those that can be obtained from the full stereophonic set-up. The control frequencies can silence any of the three banks of speakers; hence the sound from the second soundtrack can be made to originate at either side of the proscenium or to swing back and forth across the proscenium opening. However, the two side banks cannot be made to emit different sounds simultaneously. The system in short, does not have the full flexibility of the elaborate "Fantasound" setup, but it gives all the results of "trisonic" sound and in addition approaches the results of stereophonic reproduction.

In terms of equipment, it requires three channels of variable-gain amplification to Vitasound's two; three sets of speakers backstage, and control facilities for filtering, amplifying and rectifying the control frequencies. Like the trisonic system, it needs only modification of existing soundheads, not separate soundheads.

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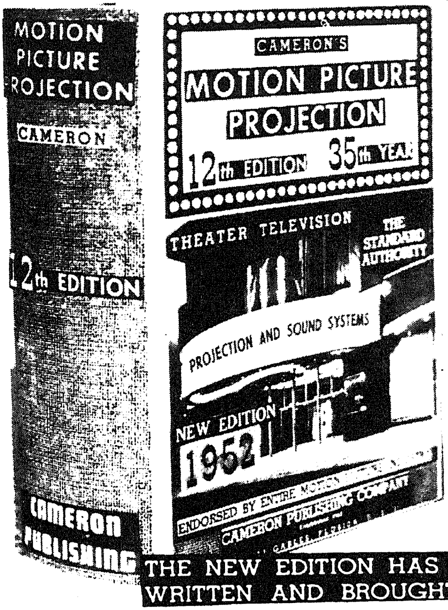

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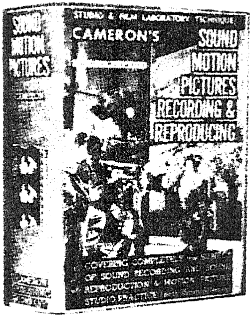
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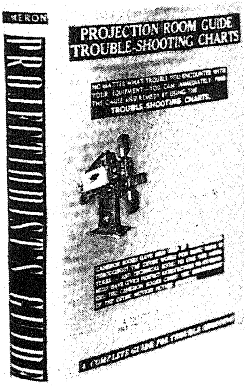

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